Thomas J.   THE   Nutall

THE COLLIERY ENGINEER

POCKET-BOOK

OF

PRINCIPLES, RULES, FORMULÆ, AND TABLES,

SPECIALLY COMPILED AND PREPARED FOR THE CONVENIENT USE OF COLLIERY OFFICIALS, MINING ENGINEERS, AND STUDENTS PREPARING THEMSELVES FOR CERTIFICATES OF COMPETENCY AS MINE INSPECTORS OR MINE FOREMEN.

GENEROUSLY ILLUSTRATED.

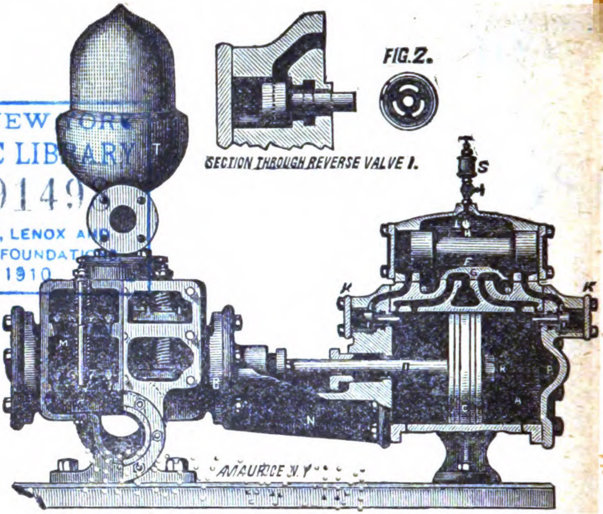
Thomas J. Foster

"Though index learning turns no student pale,
It grasps the Eel of Science by the tail."

Anon.

SCRANTON, PA.:
THE COLLIERY ENGINEER COMPANY,
COAL EXCHANGE.
1891.

THE CAMERON STEAM-PUMP



SECTIONAL VIEW.

The principle of operation of all single direct-acting steam-pumps, is the use of an auxiliary piston or plunger working in the steam-chest to drive the main slide-valve. The auxiliary piston or plunger is driven backward and forward by the pressure of the steam, carrying with it the main valve, which in turn gives steam to the main piston which operates the pump. In THE CAMERON DIRECT-ACTING PUMPS the reversing of the auxiliary piston or plunger is accomplished by the use of two small valves only, and the entire valve mechanism consists of but four strong pieces all working in a direct line with the main piston, thus making it the most simple, consequently the most durable of all the direct-acting steam-pump valve-movements.

OPERATION.—Steam is admitted to the steam-chest, and through small holes in the ends of the plunger F, fills the spaces at the ends and the ports E E as far as the reversing valves I I. With the plunger F and slide-valve G in position to the right, (as shown in cut), steam would be admitted to the right-hand end of the steam-cylinder A, and the piston C would be moved to the left. When it reaches the reversing valve I, it opens it and exhausts the space at the left-hand end of the plunger F, through the passage E; the expansion of steam at the right-hand end changes the position of the plunger F, and with it the slide-valve G, and the motion of the piston C is instantly reversed. The same operation repeated makes the motion continuous. In its movement the plunger F acts as a slide-valve to shut off the ports E E, and is cushioned on the confined steam between the ports and steam-chest cover. The reversing-valves I I are closed immediately the piston C leaves them, by a pressure of steam on their outer ends, conveyed direct from the steam-chest.

DIRECTIONS.

When a pump is first connected, remove the bonnets K K and valves I I, and blow steam through to remove any dirt or chips that may have lodged in the pipes; then clean and replace them.

Full information to the engineer sent with each pump.

For illustrated catalogue address,

THE A. S. CAMERON STEAM-PUMP WORKS,

FOOT OF EAST 23D STREET, NEW YORK.

PREFACE.

THE COLLIERY ENGINEER POCKET-BOOK is a new edition of the Mine-Foreman's Pocket-Book, enlarged and improved, so as to meet the requirements of mining engineers, mine officials, and mining students, for a convenient book of reference.

In its preparation we have kept in mind the fact that the majority of mine officials are men whose educational advantages were exceedingly limited, and therefore we have endeavored to make the work simple and plain. It is at the same time so complete in every department that it will be found valuable and useful by mining engineers and mine officers.

The book will answer a double purpose. (1.) It is a text-book for the use of mining students, and especially for the use of those who are endeavoring to prepare themselves for government examinations. (2.) It is a book of reference for all classes of mine officials and mining engineers.

To make the volume of a convenient size, and at the same time have it contain a large amount of matter, it was necessary to use a smaller size of type than would have been used if a larger-sized book had been made. However, new and clear-faced type has been used, and the convenient size of the volume will be appreciated more than larger-sized type.

We desire to extend our thanks to the numerous friends whose suggestions and data were so generously furnished to assist us in compiling the work. We also desire to acknowledge our indebtedness to the authors from whose publications we have copied extracts, all of whom are credited in the body of the book.

We will be greatly obliged to all readers and users of this volume, who will kindly call our attention to the omission of any data that they may have felt the want of, so that it may be inserted in future editions.

TABLE OF CONTENTS.

For detailed index see back of volume. See also Glossary of Mining Terms, page 212.

Strength and Weight of Materials.

Wire Ropes.

Chains.

Elements of Mechanics.

Colliery Management.

Ventilation.

Hydrostatics.

Hydraulics.

Transmission of Power by Compressed Air.

Mine-Surveying.

Mine Railways.

Colliery-Machinery.

Steam-Raising.

Miscellaneous.

Faults.

Applications of Electricity to Coal-Mining.

Glossary.

Logarithms of Numbers.

Logarithmic Sines, Cosines, Tangents, and Cotangents.

Natural Sines, Cosines, Tangents, and Cotangents.

The Traverse Table.

Squares, Cubes, Circles, Etc.

INDEX OF ADVERTISEMENTS.

COLLIERY ENGINEER POCKET-BOOK.

ARITHMETIC.

COMMON FRACTIONS.

The numerator of a fraction is the number that tells how many parts of a whole are taken. Thus, 2 is the numerator of $\frac{2}{3}$, as it shows that two of the three parts into which the whole is divided are taken.

The denominator of a fraction is the number that shows into how many parts the whole is divided. Thus, in the fraction $\frac{2}{3}$, the 3 is the denominator.

A common denominator is a denominator common to two or more fractions. Thus, $\frac{1}{4}$ and $\frac{3}{4}$ have common denominators; and again, 12 is a common denominator for $\frac{1}{6}$, $\frac{1}{3}$, $\frac{1}{4}$, and $\frac{1}{2}$, as they each are respectively equal to $\frac{2}{12}$, $\frac{4}{12}$, $\frac{3}{12}$, and $\frac{6}{12}$.

To add common fractions.—If of the same denominator, add together the numerators only. Thus. $\frac{1}{16} + \frac{3}{16} + \frac{5}{16} = \frac{9}{16}$.

If they have different denominators, change them to fractions with common denominators, and then proceed as above.

EXAMPLE.—What is the sum of $\frac{1}{3} + \frac{1}{4} + \frac{1}{5}$?

$$\tfrac{1}{3} = \tfrac{20}{60},\ \tfrac{1}{4} = \tfrac{15}{60},\ \text{and}\ \tfrac{1}{5} = \tfrac{12}{60}.$$

$$\tfrac{20}{60} + \tfrac{15}{60} + \tfrac{12}{60} = \tfrac{47}{60}.\text{—}Ans.$$

To multiply common fractions.—Multiply the numerators together for the numerator, and the denominators for the denominator. Thus $\frac{1}{2} \times \frac{3}{16} \times \frac{2}{3} = \frac{6}{96}$, or $\frac{1}{16}$.

To divide common fractions.—Invert the divisor, and multiply.

EXAMPLE.—Divide $\frac{9}{64}$ by $\frac{2}{5}$.

$$\tfrac{9}{64} \times \tfrac{5}{2} = \tfrac{45}{128}.\text{—}Ans.$$

To reduce compound fractions to simple fractions.—Multiply the integer by the denominator of the fraction, and add the numerator for the new numerator, and place it over the denominator.

EXAMPLE.—Reduce $5\frac{2}{3}$ to a simple fraction.

$5 \times 3 + 2 = 17$, or the numerator, and the fraction is therefore $\frac{17}{3}$.

To reduce simple fractions to compound fractions.—Divide the numerator by the denominator, and use the remainder as the numerator of the remaining fraction.

EXAMPLE.—Reduce $\frac{64}{9}$ to a compound fraction.

```
9)64(7
  63
  --
   1
```

Therefore the compound fraction is $7\frac{1}{9}$.

To reduce common fractions to decimal fractions.—Annex ciphers to the numerator, and divide by the denominator, and point off as many decimal-places in the quotient as there are ciphers used.

EXAMPLE.—Reduce $\frac{9}{16}$ to a decimal fraction.

```
16)9·0000(·5625.—Ans.
   8 0
   ---
   100
    96
   ---
     40
     32
     --
     80
     80
     --
```

NOTE.—Ciphers annexed to a decimal do not increase its value. 1·13 is the same as 1·1300. Every cipher placed between the first figure of a decimal and the decimal-point divides the decimal by 10. Thus,

$$\cdot13 \div 10 = \cdot013$$

DECIMALS.

Decimal fractions are fractions that have for their denominators 10 or a power of 10, as hundredths, thousandths, etc.

TABLE OF FRACTIONS REDUCED TO DECIMALS.

$\frac{1}{64}$	·015625	$\frac{17}{64}$	·265625	$\frac{33}{64}$	·515625	$\frac{49}{64}$	·765625
$\frac{1}{32}$	·03125	$\frac{9}{32}$	·28125	$\frac{17}{32}$	·53125	$\frac{25}{32}$	·78125
$\frac{3}{64}$	·046875	$\frac{19}{64}$	·296875	$\frac{35}{64}$	·546875	$\frac{51}{64}$	·796875
$\frac{1}{16}$	·0625	$\frac{5}{16}$	·3125	$\frac{9}{16}$	·5625	$\frac{13}{16}$	·8125
$\frac{5}{64}$	·078125	$\frac{21}{64}$	·328125	$\frac{37}{64}$	·578125	$\frac{53}{64}$	·828125
$\frac{3}{32}$	·09375	$\frac{11}{32}$	·34375	$\frac{19}{32}$	·59375	$\frac{27}{32}$	·84375
$\frac{7}{64}$	·109375	$\frac{23}{64}$	·359375	$\frac{39}{64}$	·609375	$\frac{55}{64}$	·859375
$\frac{1}{8}$	·125	$\frac{3}{8}$	·375	$\frac{5}{8}$	·625	$\frac{7}{8}$	·875
$\frac{9}{64}$	·140625	$\frac{25}{64}$	·390625	$\frac{41}{64}$	·640625	$\frac{57}{64}$	·890625
$\frac{5}{32}$	·15625	$\frac{13}{32}$	·40625	$\frac{21}{32}$	·65625	$\frac{29}{32}$	·90625
$\frac{11}{64}$	·171875	$\frac{27}{64}$	·421875	$\frac{43}{64}$	·671875	$\frac{59}{64}$	·921875
$\frac{3}{16}$	·1875	$\frac{7}{16}$	·4375	$\frac{11}{16}$	·6875	$\frac{15}{16}$	·9375
$\frac{13}{64}$	·203125	$\frac{29}{64}$	·453125	$\frac{45}{64}$	·703125	$\frac{61}{64}$	·953125
$\frac{7}{32}$	·21875	$\frac{15}{32}$	·46875	$\frac{23}{32}$	·71875	$\frac{31}{32}$	·96875
$\frac{15}{64}$	·234375	$\frac{31}{64}$	·484375	$\frac{47}{64}$	·734375	$\frac{63}{64}$	·984375
$\frac{1}{4}$	·25	$\frac{1}{2}$	·5	$\frac{3}{4}$	·75	1	1·0000

To add decimals.—Place the numbers in a column with whole numbers under whole numbers, tenths under tenths, hundredths under hundredths, etc., and proceed as in simple addition, placing the decimal-point in the sum directly under the points above. Thus,

```
    ·0075
    ·63
   1·06
  17·9342
  -------
  19·6317
```

To subtract decimals.—Arrange the figures as in addition, and proceed as in simple subtraction. Thus,

```
  5·96978
  3·28694
  -------
  2·68284
```

To multiply decimals.—Proceed as in simple multiplication, pointing off as many decimal-places in the result as there are decimal-places in both multiplicand and multiplier. Thus,

```
   4·67531
      ·053
 ----------
   1402593
  2337655
 ----------
 0·24779143
```

To divide decimals.—Proceed as in simple division, and point off as many decimal-places in the quotient as the number of decimal-places in the dividend exceeds those in the divisor.

EXAMPLES.—Divide 4·756 by 3·3.

```
3·3)4·75600(1·4412.—Ans.
    3 3
    ---
    145
    132
    ---
     136
     132
     ---
       40
       33
       --
       70
       66
       --
        4
```

Divide ·006 by 20.

```
20)·0060(·0003.—Ans.
     60
     --
```

SIMPLE PROPORTION, OR SINGLE RULE OF THREE.

A proportion is an expression of equality between equal ratios; thus, the ratio of 10 to 5 = the ratio of 4 to 2, and is expressed thus:

$$10 : 5 :: 4 : 2$$

There are four terms in proportion. The first and last are the *extremes*, and the second and third are the *means*.

Quantities are in proportion by *alternation* when antecedent is compared with antecedent and consequent with consequent. Thus, if 10 : 5 :: 4 : 2, then 10 : 4 :: 5 : 2.

Quantities are in proportion by *inversion* when the antecedents are made consequents and the consequents antecedents. Thus, if 10 : 5 :: 4 : 2, then 5 : 10 :: 2 : 4.

In any proportion the product of the means will equal the product of the extremes. Thus, if 10 : 5 :: 4 : 2, then $5 \times 4 = 10 \times 2$.

A mean proportional between two quantities equals the square root of their product. Thus, a mean proportional between 12 and 3 = the square root of 12×3, or 36. Therefore the mean proportional is 6, and the equation stands 12 : 6 :: 6 : 3.

If the two means and one extreme of a proportion are given, we find the other extreme by dividing the product of the means by the given extreme. Thus, 10 : 5 :: 4 : ( ), then $(4 \times 5) \div 10 = 2$, and the proportion is 10 : 5 :: 4 : 2.

If the two extremes and one mean are given, we find the other mean by dividing the product of the extremes by the given mean. Thus, 10 : ( ) :: 4 : 2, then $(10 \times 2) \div 4 = 5$, and the proportion is 10 : 5 :: 4 : 2.

EXAMPLES IN SIMPLE PROPORTION.

If 6 men load 30 wagons of coal in a day, how many wagons will 10 men load? (They will evidently load more, so the second term of the proportion must be greater than the first.)

Ans.—6 : 10 :: 30 : ( ); then $(10 \times 30) \div 6 = 50$.

If 4 men do a certain piece of work in 12 hours, in what time will 6 men do it? (They will evidently do it in less time, so the second term of the proportion must be less than the first.)

Ans.—6 : 4 :: 12 : ( ); then $(4 \times 12) \div 6 = 8$ hrs.

COMPOUND PROPORTION, OR DOUBLE RULE OF THREE.

PRINCIPLES.

1. The product of the simple ratios of the first couplet = the product of the simple ratios of the second couplet. Thus,

$$\left\{\begin{matrix}4 : 12\\7 : 14\end{matrix}\right\} :: \left\{\begin{matrix}5 : 10\\6 : 18\end{matrix}\right\} = \frac{4}{12} \times \frac{7}{14} = \frac{5}{10} \times \frac{6}{18}$$

2. The product of all the terms in the extremes = the product of all the terms in the means. Thus, in

$$\left\{\begin{matrix}4 : 12\\7 : 14\end{matrix}\right\} :: \left\{\begin{matrix}5 : 10\\6 : 18\end{matrix}\right\} \text{ we have, } 4 \times 7 \times 10 \times 18 = 12 \times 14 \times 5 \times 6.$$

3. Any term in either extreme = the product of the means divided by the product of the other terms in the extremes. Thus, in the same proportion we have

$$4 = \frac{5 \times 6 \times 12 \times 14}{7 \times 10 \times 18}$$

4. Any term in either mean = the product of the extremes divided by the product of the other terms in the means. Thus, in

$$\left\{\begin{matrix} 4 : 12 \\ 7 : 14 \end{matrix}\right\} :: \left\{\begin{matrix} 5 : 10 \\ 6 : 18 \end{matrix}\right\}$$

we have, $5 = (4 \times 7 \times 10 \times 18) \div (6 \times 12 \times 14)$.

RULE.—*I. Put the required quantity for the first term and the similar known quantity for the second term, and form ratios with each pair of similar quantities for the second couplet, as if the result depended on each pair and the second term.*

II. Find the required term by dividing the product of the means by the product of the fourth terms.

EXAMPLES.—If 4 men can earn \$24 in 7 days, how much can 14 men earn in 12 days?

$$\text{The sum} : \$24 :: \left\{\begin{matrix} 14 : 4 \\ 12 : 7 \end{matrix}\right\} \text{ or, The sum} = \frac{24 \times 14 \times 12}{4 \times 7} = \$144.\text{—}\mathit{Ans.}$$

If 12 men in 35 days build a wall 140 rods long, 6 ft. high, how many men can, in 40 days, build a wall of the same thickness 144 rods long, 5 ft. high?

$$\left\{\begin{matrix} (\;) : 12 \\ 35 : 40 \end{matrix}\right\} :: \left\{\begin{matrix} 140 : 144 \\ 6 : 5 \end{matrix}\right\} = \frac{12 \times 40 \times 140 \times 6}{35 \times 144 \times 5} = 9.\text{—}\mathit{Ans.}$$

INVOLUTION.

To square a number.—Multiply the number by itself. Thus, the square of 4 = 4×4, or 16.

To cube a number.—Multiply the square of the number by the number. Thus, the cube of $4 = 16 \times 4 = 64$.

To find the fourth power of a number.—Multiply the cube by the number. Thus, the fourth power of $4 = 64 \times 4 = 256$.

To raise a number to the sixth power.—Square its cube.

To raise a number to the twelfth power.—Square its sixth power.

(See table of logarithms for a shorter method.)

EVOLUTION.

To find the square root of a number.—

RULE.—*I. Separate the given number into periods of two figures each, beginning at the units place.*

II. Find the greatest number whose square is contained in the period on the left; this will be the first figure in the root. Subtract the square of this figure from the period on the left, and to the remainder annex the next period to form a dividend.

III. Divide this dividend, omitting the figure on the right, by double the part of the root already found, and annex the quotient to that part, and also to the divisor; then multiply the divisor thus completed by the figure of the root last obtained, and subtract the product from the dividend.

IV. If there are more periods to be brought down, continue the operation as before.

EXAMPLE.—Find the square root of 874225.

```
87,42,25(935.—Ans.
81
 642
 549
  9325
  9325
```

OPERATION.

$9 \times 2 = 18$. 18 into 64 goes 3 times, hence new divisor = 183. $93 \times 2 = 186$. 186 into 932 goes 5 times, hence new divisor = 1865.

(See table of logarithms for shorter method.)

The square root of a fraction is found by extracting the square root of the numerator and denominator separately. Thus, the square root of $\frac{9}{64} = 3/8$.

To find the cube root of a number.—

RULE.—*I. Separate the given number into periods of three figures each, beginning at the units place.*

II. Find the greatest number whose cube is contained in the period on the left; this will be the first figure in the root. Subtract the cube of this figure from the period on the left, and to the remainder annex the next period to form a dividend.

III. Divide this dividend by the partial divisor, which is 3 times the square of the root already found, considered as tens; the quotient is the second figure of the root.

IV. To the partial divisor add 3 times the product of the second figure of the root by the first considered as tens, also the square of the second figure; the result will be the complete divisor.

V. Multiply the complete divisor by the second figure of the root, and subtract the product from the dividend.

VI. If there are more periods to be brought down, proceed as before, using the part of the root already found, the same as the first figure in the previous process.

EXAMPLE.—Find the cube root of 12812904.

OPERATION.

	12,812,904(234.—*Ans.*
$2^3 =$	8
1st partial divisor, $3 \times 20^2 = 1200$	4812
$3 \times 20 \times 3 = 180$	
$3^2 = 9$	4167
1st complete divisor, 1389	645904
2d partial divisor, $3 \times 230^2 = 158700$	
$3 \times 230 \times 4 = 2760$	
$4^2 = 16$	645904
2d complete divisor 161476	

The cube root of a fraction is found by extracting the cube root of the numerator and denominator separately. Thus, the cube root of $\frac{27}{64} = \frac{3}{4}$.

(See table of logarithms for shorter method.)

PERCENTAGE.

Percentage means by or on the hundred. Thus, 1% = 1 on 100, 3% = 3 on 100, 5% = 5 on 100, etc.

To find the percentage, having the rate and the base.—Multiply the base by the rate expressed in hundredths. Thus, 6% of 1930 is found thus:

$$\begin{array}{r} 1930 \\ .06 \\ \hline 115.80 \end{array}$$

To find the amount, having the base and rate.—Multiply the base by 1 plus the rate. Thus, to find the amount of \$1930 for one year at 6%, we multiply 1930 by 1.06.

\$1930 × 1.06 = \$2,045.80

To find the base, having the rate and the percentage.—Divide the percentage by the rate to find the base. Thus, if the rate is 6% and the percentage is 115.80, the base = 115.80 ÷ .06 = 1930.

To find the rate, having the percentage and the base.—Divide the percentage by the base. Thus, if the percentage is 115.80 and the base 1930 the rate equals 115.80 ÷ 1930 = .06, or 6%.

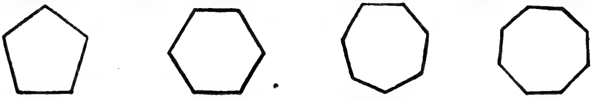
the areas of the two triangles, and the sum will equal the area of the trapezium. The sides and angles can be found in the same manner.

To find the area of a trapezium.—If the diagonals and the perpendiculars from them to the opposite angles are given, add together the two perpendiculars, multiply the sum by the diagonal, and divide by 2.

The sum of the four angles included in a trapezium always equals four right angles.

POLYGONS.

All figures bounded by more than four straight lines are called polygons.



Pentagon. Hexagon. Heptagon. Octagon.

If all the sides and angles are equal it is a regular polygon. If not, it is an irregular polygon.

The sum of the interior angles of any polygon are equal to twice as many right angles as the polygon has sides less four right angles.

TABLE OF REGULAR POLYGONS WHOSE SIDES ARE UNITY.

Number of Sides.	Name of Polygon.	Areas.	Outer Radii.	Angles Contained between Two Sides.	Angle at Center of Circle.
3	Equilateral Triangle	·4330	·5774	60°	120°
4	Square	1·0000	·7071	90°	90°
5	Pentagon	1·7205	·8507	108°	72°
6	Hexagon	2·5981	1·0000	120°	60°
7	Heptagon	3·6339	1·1524	128° 34′ 17+″	51° 25′ 43−″
8	Octagon..................	4·8284	1·3066	135°	45°
9	Nonagon	6·1818	1·4619	140°	40°
10	Decagon	7·6942	1·6180	144°	36°
11	Undecagon	9·3656	1·7747	147° 16′ 22−″	32° 43′ 38+″
12	Dodecagon	11·1962	1·9319	150°	30°

To find the area of any regular polygon.—Square one of its sides and multiply by the number given in the column of areas above. Or, multiply the length of one of the sides by one half the length of a perpendicular drawn to the center of the figure, and this product by the number of sides.

Having the side of a regular polygon, to find the radius of a circumscribing circle.—Multiply the side by the corresponding number in foregoing column of outer radii.

If you have the radius of the circumscribing circle, divide it by the number in column of outer radii, and the quotient will be the side of the polygon.

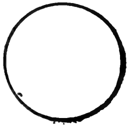
To find the area of an irregular polygon.—Divide it into triangles, find the area of each triangle, and add them together. The sum will be the area of the polygon.

To find the area of a figure whose outlines are very irregular.—Draw straight lines around it that will inclose within them (as nearly as can be judged) as much space not belonging to the figure as they exclude space belonging to it. The area of the figure thus formed may be easily found by dividing into triangles.

CIRCLES.

See Table of Areas of Circles, etc.

A circle is a figure bounded by a curved line, every point of which is equidistant from the center. Or, a circle is a regular polygon of an infinite number of sides.



The circumference of a circle equals the diameter multiplied by 3·1416. or the square root of the product of the area multiplied by 12·566.

To find the diameter.—Divide the circumference by 3·1416 or multiply it by ·31831,

To find the area of a circle.—Multiply the circumference by one-fourth of the diameter, or the square of the radius by 3·1416.

Multiply the square of the diameter by ·7854, or the square of the circumference by ·07958.

To find the diameter of a circle equal in area to a given square.—Multiply one side of the square by 1·12838.

To find the radius of a circle to circumscribe a given square.—Multiply one side by ·7071; or take one-half the diagonal.

To find the side of a square equal in area to a given circle.—Multiply the diameter by ·88623.

To find the side of the greatest square in a given circle.—Multiply the diameter by ·7071.

To find the area of the greatest square in a given circle.—Square the radius and multiply by 2.

To find the side of an equilateral triangle equal in area to a given circle.—Multiply the diameter by 1·3468.

Having the chord and rise of an arc, to find the radius.—Square half the chord, and divide by the rise. To the quotient add the rise, and divide by 2.

Or, Radius = the square of the chord of half the arc divided by twice the rise of the whole arc.

Having the chord and radius, to find the rise.—Square the radius, also square half the chord. Take the last square from the first. Extract square root of the remainder, and subtract it from the radius if the radius is greater; if not, add it to the radius.

Having the radius and rise, to find the chord.—From the radius subtract the rise (or from the rise subtract the radius if rise is the greater), square the remainder, and subtract it from the square of the radius. Extract the square root of the remainder, and multiply by 2.

Having the rise of the arc and diameter of circle, to find the chord.—Subtract the rise from the diameter, and multiply the remainder by the rise. Extract the square root of the product, and multiply by 2.

To find the breadth of a circular ring, having its area and the diameter of the outer circle.—Find the area of the whole circle, and from it take the area of the ring. Multiply the remainder by 1·2732, and the square root of the product will be the diameter of the inner circle. Take it from the diameter of the outer one, and the remainder will be twice the breadth.

To find the area of a circular ring.—Take the difference of the squares of the radii, and multiply it by 3·1416.

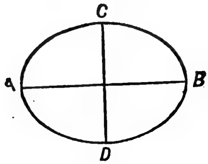
To find the length of an arc when its degrees and radius are given.—Multiply the number of degrees by ·01745, and the product by the radius.

To find the area of sector.—Multiply the arc by ½ the radius.

The area of the sector is to the area of the circle as the number of degrees in the sector is to 360°.

To find the area of a segment.—Find the area of the sector having the same arc, and also the area of the triangle formed by the chord of the segment and the radii of the sector. If the segment is greater than a semicircle, add the two areas; if less, subtract them.

THE ELLIPSE.



To find the area of an ellipse.—Multiply ½ of the two axes A B and C D together, and multiply the product by 3·1416.

MENSURATION OF VOLUMES.

THE CUBE AND THE PARALLELOPIPED.

To find the surface of a cube.—Multiply the area of one side by 6.

To find the surface of a parallelopiped.—Add together twice the area of the base, twice the area of the side, and twice the area of the end.

To find the cubical contents of a cube or parallelopiped.—Multiply the area of the base by the perpendicular height.

THE PRISM.

To find the convex surface of a right prism.—Multiply the perimeter of the base by the altitude.

To find the entire surface, add the areas of the bases.

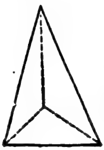
To find the contents of a prism.—Multiply the area of the base by the altitude of the prism.

THE PYRAMID.

To find the convex surface of a pyramid.—Multiply the perimeter of the base by ½ the slant height.

To find the entire surface, add the area of the base.

To find the contents of a pyramid.—Multiply the area of the base by ⅓ of the altitude.



THE CYLINDER.

To find the convex surface of a cylinder.—Multiply the circumference of the base by the altitude.

To find the entire surface, add the areas of the ends.

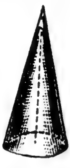
To find the contents of a cylinder.—Multiply the area of the base by the altitude.

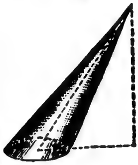
THE CONE.

To find the convex surface of a cone.—Multiply the circumference of the base by ½ the slant height.

To find the entire surface, add the area of the base.

To find the contents of a cone.—Multiply the area of the base by ⅓ of the altitude.



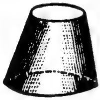


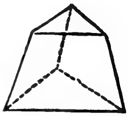
THE FRUSTUM OF A PYRAMID OR CONE.

To find the convex surface.—Multiply ½ of the sum of the perimeters or circumferences of the two bases by ½ the slant height.

The entire surface is found by adding the areas of the two bases.

To find the contents of a frustum.—Add together the sum of the two bases and the square root of their product, and multiply the sum by ⅓ of the altitude of the frustum.





THE SPHERE.

To find the surface of a sphere.—Multiply the diameter by the circumference; or, square the radius and multiply it by 4 and 3·1416.

To find the contents of a sphere.—Multiply the surface by ⅓ of the radius; or, multiply the cube of the diameter by ·5236.

To find the surface of a zone.—Multiply the height of the zone by the circumference of a great circle of the sphere.

To find the contents of a spherical segment of one base.—Add the square of the height to three times the square of the radius of the base; multiply this sum by the height, and the product by ·5236.

CYLINDRICAL RINGS.

A cylindrical ring is formed by bending a cylinder or pipe until its two ends meet.

To find the surface of a cylindrical ring.—To the thickness of the ring add the inner diameter, multiply this sum by the thickness of the ring, and the product by 9·8696.

To find the contents of a cylindrical ring.—To the thickness of the ring add the inner diameter, multiply this sum by the square of $\frac{1}{2}$ the thickness.

To find the volume of an irregular body.—Fill a vessel of known dimensions with water, and immerse the body. The contents will equal the volume of water displaced.

THE PRISMOIDAL FORMULA.

This formula is the invention of Mr. Elwood Morris, C. E., of Philadelphia, and is extensively used in calculating the cubical contents of cuttings, embankments, etc.

It embraces all parallelopipeds, prisms, pyramids, cones, wedges, etc. etc., whether regular or irregular, right or oblique, with their frustums when cut parallel to their bases. In fact, it embraces all solids having two parallel faces or sides, provided these two faces are united by surfaces, whether plane or curved, upon which and through every point of which, a straight line may be drawn from one of the parallel faces to the other.

To find the contents of any prismoid.—Add together the areas of the two parallel surfaces, and four times the area of the section taken half way between them, and parallel to them; multiply the sum by the perpendicular distance between the two parallel sides, and divide the product by 6.

GEOMETRY.

THE PRINCIPLES OF GEOMETRY.

1. The sum of all the angles formed on one side of a straight line equals two right angles, or 180°.
2. The sum of all the angles formed around a point equals four right angles, or 360°.
3. When two straight lines intersect each other, the opposite or vertical angles are equal.
4. If two angles have their sides parallel they are equal.
5. If two triangles have two sides and the included angle of the one, equal to two sides and the included angle of the other, they are equal in all their parts.

If two triangles have two angles and the included side of one equal to two angles and the included sides of the other, they are equal in all their parts.

6. In any triangle the greater side is opposite the greater angle, and the greater angle is opposite the greater side.
7. In an isosceles triangle the angles opposite the equal sides are equal.
8. In any triangle the sum of the three angles is equal to two right angles, or 180°.
9. If two angles of a triangle are given, the third may be found by subtracting their sum from two right angles, or 180°.
10. A triangle must have at least two acute angles, and can have but one obtuse, or one right angle.
11. In any triangle a perpendicular let fall from the apex to the base is shorter than either of the two other sides.
12. In any parallelogram the opposite sides and angles are equal each to each.
13. The diagonals divide any parallelogram into two equal triangles,

14. The diagonals of a parallelogram bisect each other; that is, they divide each other into equal parts.

15. If the sides of a polygon be produced in the same direction the sum of the exterior angles will equal four right angles.

16. The sum of the interior angles of a polygon is equal to twice as many right angles as the polygon has sides, less four right angles.

EXAMPLES.

The sum of the interior angles of a quadrilateral = $(2 \times 4) - 4 = 4$ right angles.

The sum of the interior angles of a pentagon = $(2 \times 5) - 4 = 6$ right angles.

The sum of the interior angles of a hexagon = $(2 \times 6) - 4 = 8$ right angles.

17. In equiangular polygons each interior angle equals the sum divided by the number of sides.

18. The square described on the hypothenuse of a right-angled triangle is equal to the sum of the squares described on the other two sides. Thus, in a right-angled triangle whose base is 20 ft. and its altitude 10, the square of the hypothenuse equals the square of 20 + the square of 10, or 500. Then the hypothenuse equals the square root of 500, or 22·3607 ft.

19. Having the hypothenuse and one side of a right-angled triangle, the other side may be found by subtracting from the square of the hypothenuse the square of the other known side. The remainder will be the square of the required side.

20. Triangles which have an angle in each equal, are to each other as the product of the sides including those equal angles.

21. Similar triangles are to each other as the squares of their corresponding sides.

22. The perimeters of similar polygons are to each other as any two corresponding sides, and their areas are to each other as the squares of those sides.

23. The diameter of a circle is greater than any chord.

24. Any radius which is perpendicular to a chord, bisects the chord and the arc subtended by the chord.

25. Through three points not in the same line a circumference may be made to pass.

DIRECTIONS.—Draw two lines connecting the three points. Erect perpendiculars from the centers of each of these two lines, and the point of intersection of the perpendiculars will be the center of the circle.

26. The circumferences of circles are to each other as their radii, and their areas are to each other as the squares of their radii.

EXAMPLES.

If the circumference of a circle is 62·83 in. and its radius is 10 in., what is the circumference of a circle whose radius is 15 in.?

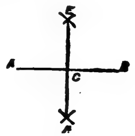
Ans.—10 : 15 :: 62·83 : 94·245 in.

If a circle 6 in. in diam. has an area of 28·274 sq. in., what is the area of a circle 12 in. in diameter?

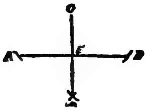
Ans.—$3^2 : 6^2$ :: 28·274 : 113·096 sq. in.

PRACTICAL PROBLEMS IN GEOMETRICAL CONSTRUCTION.

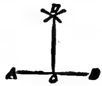
To bisect a given straight line.—Let A B be a given straight line. From A and B as centers, with a radius greater than one-half of A B describe arcs intersecting each other at E and F. Then draw the line E F. It will bisect A B, and C will be the middle point, and E F will be perpendicular to A B. The points E and F will be equidistant from A, B, or C.



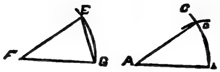
From a given point, without a straight line, to draw a perpendicular to the line.—Let A B be the given line and C the given point. From C as a center, with a radius sufficiently great, describe an arc cutting the line A B in the two points A and B; then from A and B as centers, with a radius greater than ½ of A B, describe two arcs cutting each other at D, and draw C D.



At a given point in a straight line, to erect a perpendicular to that line.—Let A B be the given line, and C the given point. Then in the line A B take the points A and B equally distant from C, and, with A and B as centers, and a radius greater than ½ of A B, describe two arcs cutting each other at D, and draw the line D C.

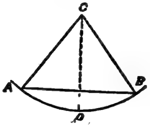


At a point on a given straight line, to make an angle equal to a given angle.—Let A be the given point, A B the given line, and E F G the given angle. From F as a center, with any radius F G describe the arc E G. From A as a center, with the same radius, describe the arc C B; then with a radius equal to the chord E G, describe an arc from B as a center, cutting C B at D, and draw A D.

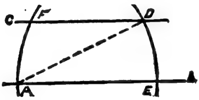


To bisect a given arc, or a given angle.—1st. Let A D B be the given arc, and C its center. Draw the chord A B, and from C draw C D perpendicular to A B.

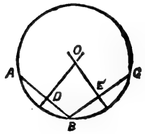
2d. Let A C B be the given angle. Then, with C as a center and any radius, describe the arc A D B, and bisect this as above.



Through a given point to draw a straight line parallel to a given straight line.—Let A be the given point and C D the given line. From A as a center, with a radius greater than the shortest distance from A to C D, describe an indefinite arc D E. From D as a center, with the same radius, describe the arc A F. Take D E equal to A F, and draw A B.

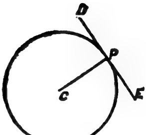


To find the center of a given circumference or arc.—Take any three points, A, B, and C, on the circumference, and unite them by the lines A B and B C. Bisect these chords by the perpendiculars D O and E O; their intersection is the center of the circle.



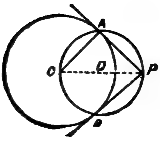
Through a given point to draw a tangent to a given circle.—1. Suppose the given point P to be in the circumference.

Find C, the center of the circle, draw the radius C P, and draw D E perpendicular to C P.



2. Suppose the given point P to be without the circle.

Join P and the center of the circle. Bisect P C in D; with D as a center, and a radius D C, describe the circumference intersecting the given circumference at A and B. From the intersections A and B draw B P and A P.

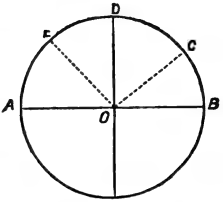


PLANE TRIGONOMETRY.

Plane Trigonometry treats of the solution of plane triangles.

In every triangle there are six parts; three sides and three angles. These parts are so related that when three of the parts are given, one being a side, the other parts may be found.

An angle is measured by the arc included between its sides, the center of the circumference being at the vertex of the angle.



For measuring angles the circumference is divided into 360 equal parts, called degrees; each degree into 60 equal parts called minutes.

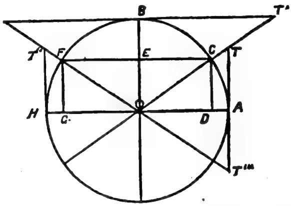
A **Quadrant** is ¼ of the circumference of a circle, or 90°.

The **Complement** of an arc is 90° minus the arc; D C is the complement of B C, and the angle D O C is the complement B O C.

The **Supplement** of an arc is 180° minus the arc; A E is the supplement of the arc B D E, and the angle B O E.

In Trigonometry, instead of comparing the angles of triangles or the arcs which measure them, we compare the *sine, cosine, tangent, cotangent, secant, and cosecant.*

The **Sine** of an arc is the perpendicular let fall from one extremity of the arc on the diameter which passes through the other extremity. Thus, C D is the sine of the arc A C.



The **Cosine** of an arc is the sine of its complement; or it is the distance from the foot of the sine to the center of the circle. Thus, C E or O D = the cosine of arc A C.

The **Tangent** of an arc is a line which is perpendicular to the radius at one extremity of an arc and limited by a line passing through the center of the circle and the other extremity. Thus, A T is the tangent of A C.

The **Cotangent** of an arc is equal to the tangent of the complement of the arc. Thus, B T' is the cotangent of A C.

The **Secant** of an arc is a line drawn from the center of the circle through one extremity of the arc, and limited by a tangent at the other extremity. Thus, O T is the secant of A C.

The **Cosecant** of an arc is the secant of the complement of the arc. Thus, O T' is the cosecant of A C.

From the above definitions we derive the following simple principles:

1. The sine of an arc = the sine of its supplement, and the cosine of an arc = the cosine of its supplement.

2. The tangent of an arc = the tangent of its supplement, and the cotangent of an arc = the cotangent of its supplement.

3. The secant of an arc = the secant of its supplement, and the cosecant = the cosecant of its supplement.

Thus,	The sine	of 70° =	the sine	of 110°.
	The cosine	of 70° =	the cosine	of 110°.
	The tangent	of 70° =	the tangent	of 110°.
	The cotangent	of 70° =	the cotangent	of 110°.
	The secant	of 70° =	the secant	of 110°.
	The cosecant	of 70° =	the cosecant	of 110°.

Thus, if you want to find the sine of an angle of 120° 30′, look for the sine of 180° — 120° 30′, or 59° 30′, etc.

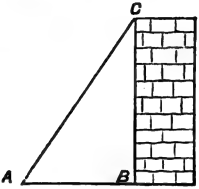
Natural sines, tangents, etc., are calculated for a circle whose radius is unity, and logarithmic sines, tangents, etc., are calculated for a circle whose

radius is 10,000,000,000. With natural sines, tangents, etc., long and tedious operations in multiplication and division are necessary.

With logarithmic sines, tangents, etc., these operations, in conjunction with the table of logarithms of numbers, are reduced to simple addition and subtraction. (See tables in back of book.)

PRACTICAL EXAMPLES IN THE SOLUTION OF TRIANGLES.

CASE 1.—**To determine the height of a vertical object standing on a horizontal plane.**—Measure from the foot of the object any convenient horizontal distance A B; at the point A take the angle of elevation B A C. Then as B is known to be a right angle we have two angles and the included side of a triangle.

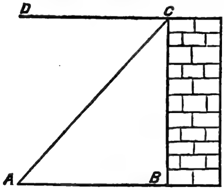


Assuming that the line A B is 300 ft., and the angle B A C = 40°, the angle C = 180° – (90° + 40°) = 50°. Then sine C : A B :: sine A : B C, or, ·766044 : 300 :: ·642788 : ( ), or 251·73+ ft.

Or, by logarithms:

Log. 300 =	2·477121
Log. sine 40° =	9·808067
	12·285188
Log. sine 50° =	9·884254
	2·400934 or log. of 251·73+ ft. Hence, B C = 251·7+ ft.

CASE 2.—**To find the distance of a vertical object whose height is known.**—At a point A take the angle of elevation to the top of the object. Knowing that the angle B is a right angle we have the angles B and A and the side B C.

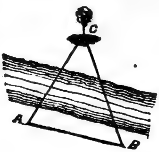


Assuming that the side B C = 200 ft. and the angle A = 30°, we have a triangle as follows: Angle A = 30°, B = 90°, C = 60°, and the side B C = 200 ft.

Then sine A : B C :: sine C : A B, or, ·5 : 200 :: ·866025 : ( ), or 346·41 ft. By logarithms:

Log. 200 =	2·301030
Log. sine 60° =	9·937531
	12·238561
Log. sine 30° =	9·698970
	2·539591 or logarithm of 346·41 ft.

CASE 3.—**To find the distance of an inaccessible object.**—Measure a horizontal base-line A B, and take the angles formed by the lines B A C and A B C. We then have two angles, and the included side. Assuming the angle A to be 60°, the angle B, 50°, and the side A B = 500 ft., we have the angle C = 90° – (60° + 50°) = 80°.



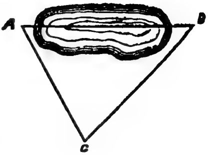
Then, sine 80° : A B :: sine A : B C, and
sine 80° : A B :: sine B : A C,
or ·984801 : 500 :: ·866025 : B C, or 439·7–.
and ·984801 : 500 :: ·766044 : A C, or 388·9+.

By logarithms:

Log. 500 =	2·698970
Log. sine 60° =	9·937531
	12·636501
Log. sine 80° =	9·993351
	2·643150 = log. of 439·7–, and
Log. 500 =	2·698970
Log. sine 50° =	9·884254
	12·583224
Log. sine 80° =	9·993351
	2·589873 = log. of 388·9+.

CASE 4.—**To find the distance between two objects separated by an impassable barrier.**—Select any convenient station, as C, measure the lines C A

and C B, and the angle included between these sides. Then, we have two sides and the included angle.



Assuming the angle C to be 60°, the side C A, 600 ft., and the side C B, 500 ft., we have the following formula:— $CA + CB : CA - CB :: \text{tang.} \frac{A+B}{2} : \text{tang.} \frac{B-A}{2}$. Then, $\frac{A+B}{2} = \frac{180^\circ - 60^\circ}{2}$, or 60°.

Then, $1{,}100 : 100 :: \text{tang. } 60^\circ : \text{tang.} \frac{B-A}{2}$, or

$1{,}100 : 100 :: 1{\cdot}732050 : {\cdot}157459$, or tangent of $\frac{B-A}{2}$, or 8° 57′.

Then, 60° + 8° 57′ = 68° 57′, or angle B, and
60° − 8° 57′ = 51° 03′, or angle A.

Having found the angles, find the third side by same method as Case 1.

The above formula worked out by logarithms is as follows:

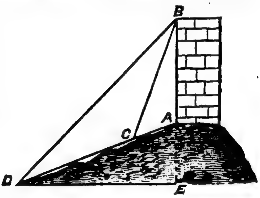
$$\begin{array}{rr} \text{Log. } 100 = & 2{\cdot}000000 \\ \text{Log. tang. } 60^\circ = & 10{\cdot}238561 \\ \hline & 12{\cdot}238561 \\ \text{Log. } 1{,}100 = & 3{\cdot}041393 \\ \hline \end{array}$$

$9{\cdot}197168 = \text{log. tang. of } \frac{B-A}{2}$, or 8° 57′.

Then, 60° + 8° 57′ = 68° 57′, or angle B, and
60° − 8° 57′ = 51° 03′, or angle A.

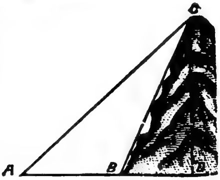
NOTE.—The greater angle is always opposite the greater side.

CASE 5.—To find the height of a vertical object standing upon an inclined plane.—Measure any convenient distance D C on a line from the foot of the object, and at the point D, measure the angles of elevation, E D A, and E D B, to foot and top of tower. We then have two triangles, both of which may be solved by Case 1, and the height above D of both the foot and top will be known. The difference between them is the height of the tower.

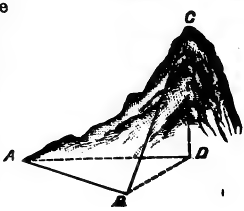


CASE 6.—To find the height of an inaccessible object above a horizontal plane. Measure any convenient horizontal line A B directly toward the object, and take the angles of elevation at A and B. We will then have sufficient data to work with. Assuming the line A B to be 1,200 ft. long, the angle A, 25°, and the angle B, 40°, we have the following: As the angle D B C is 40°, the angle A B C = 90° − 40°, or 50°.

Then, having the side B C, and the angle D B C = 40°, and the angle B D C = 90°, we find the side C D by the same method as in Case 1.



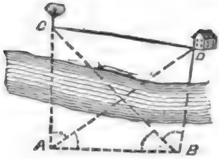
Second Method.—If it is not convenient to measure a horizontal base-line towards the object, measure any line A B, and also measure the horizontal angles B A D, A B D, and the angle of elevation, D B C. Then, by means of the two triangles, A B D and C B D, the height C D can be found. Then, with the line A B and the angles, B A D and A B D known, we have two angles and the included side known. The third angle is readily found, and the side B D can be found. Then, in the triangle B D C, we have the angle B, by measurement, D = 90°, and we have the side, B D. Then the side C D, or the vertical height, can be found by Case 1.



Case 7.—To find the distance between two inaccessible objects when points can be found from which both objects can be seen.—Wishing to know the horizontal distance between a tree and a house on the opposite side of a river, measure the line A B, and at point A take the angles D A C and D A B, and at the point B, take the angles C B A and C B D.

Assuming the length of A B = 400 ft.

The angle D A C = 56° 30′.
The angle D A B = 42° 24′.
The angle C B A = 44° 36′.
The angle C B D = 68° 50′.



In the triangle A B D, we have A B 400 = ft., the angle D A B = 42° 24′, and the angle A B D = (44° 36′ + 68° 50′) = 113° 26′, and the angle A D B = 180° − (42° 24′ + 113° 26′) = 24° 10′. Then, according to Case 1, find the side D B. We then have three angles and two sides of the triangle A D B. We find the third side, A D, by Case 1.

Then in the triangle A B C, we have the angles A B C and B A C, and the distance A B. From these we find the side A C. Then, in the triangle A D C, we have the sides A D and A C, and the angle D A C, and we then find the side C D, by Case 4.

WEIGHTS AND MEASURES.

TROY WEIGHT.

24 grains	= 1 pennyweight.	
20 pennyweights	= 1 ounce	= 480 grains.
12 ounces	= 1 pound	= 5,760 grains = 240 dwt.

In Troy, Apothecaries, and Avoirdupois weights the grains are the same.

APOTHECARIES WEIGHT.

20 grains	= 1 scruple.	
3 scruples	= 1 dram,	= 60 grains.
8 drams	= 1 ounce	= 480 grains, = 24 scruples.
12 ounces	= 1 pound	= 5,760 grains, = 288 scruples, = 96 drams.

AVOIRDUPOIS WEIGHT.

27·34375 grains	= 1 dram.	
16 drams	= 1 ounce	= 437½ grains.
16 ounces	= 1 pound	= 7,000 grains, = 256 drams.
28 pounds	= 1 quarter	= 448 ounces.
4 quarters	= 1 hundredweight	= 112 lbs.
20 hundredweight	= 1 ton	= 2,240 lbs.
	A stone	= 14 lbs.
	A quintal	= 100 lbs.
	A "short ton"	= 2,000 lbs.

1 oz. Troy or Apothecaries'	= 1·09714	Avoirdupois oz.
1 pound Troy or Apothecaries	= ·82286	lb. Avoirdupois.
1 oz. Avoirdupois	= ·911458	Troy, or Apothecaries' oz.
1 pound Avoirdupois	= 1·21528	lbs. Troy, or Apothecaries'.

METRIC WEIGHT.

10 Milligrammes	= 1 Centigramme,	=	·15432	grains.
10 Centigrammes	= 1 Decigramme,	=	1·5432	grains.
10 Decigrammes	= 1 Gramme,	=	15·432	grains.
10 Grammes	= 1 Decagramme,	=	·022046	lbs. Avoir.
10 Decagrammes	= 1 Hectogramme,	=	·22046	lbs. Avoir.
10 Hectogrammes	= 1 Kilogramme,	=	2·2046	lbs. Avoir.
10 Kilogrammes	= 1 Myriogramme,	=	22·046	lbs. Avoir.
10 Myriogrammes	= 1 Quintal,	=	220·46	lbs. Avoir.
10 Quintals	= 1 Tonneau, Millier, or Tonne,	=	2,204·	lbs. Avoir.

MEASURES OF LENGTH.

AMERICAN AND BRITISH.

12 inches	= 1 foot.				
3 feet	= 1 yard	= 36 in.			
6 feet	= 1 fathom	= 2 yds.	= 72 in.		
66 feet	= 1 chain *	= 11 fath.	= 22 yds.	= 792 in.	
10 chains	= 1 furlong	= 110 fath.	= 220 yds.	= 660 ft.	= 7,620 in.
8 furlongs	= 1 mile	= 80 chains	= 880 fath.	= 1,760 yds.	= 5,280 ft. = 63,360 in.

* The chain of 66 ft. is practically obsolete. Chains of 50 or 100 ft. are now used exclusively, by American surveyors.

To reduce inches to decimals of a foot.—Divide the number of inches by 12. Thus 7 inches = 7 ÷ 12, or ·58333 ft. To reduce fractions of inches to decimals of a foot, divide the fraction by 12, and then divide the numerator of the quotient by the denominator. Thus, $\frac{3}{8}$ inch = $\frac{3}{8}$ ÷ 12 = $\frac{3}{96}$. $\frac{3}{96}$ = ·0313 ft.

METRIC SYSTEM.*

10 Millimetres	= 1 Centimetre	= 0·3937079 in.
10 Centimetres	= 1 Decimetre	= 3·937079 in.
10 Decimetres	= 1 Metre	= 3·2808992 ft.
10 Metres	= 1 Decameter	= 10·9363 yds.
10 Decametres	= 1 Hectometre	= 109·363 yds.
10 Hectometres	= 1 Kilometre	= 0·6213824 mile.
10 Kilometres	= 1 Myriametre	= 6·213824 miles.

* Used in France, Spain, Belgium, Portugal, and Italy.

RUSSIAN.

12 inches	= 1 foot	= 1 American foot.
7 feet	= 1 saschen, or sagene.	
500 saschen	= 1 verst	= 3,500 feet.

PRUSSIAN, DANISH, AND NORWEGIAN.

12 inches	= 1 foot	= 1·02972 American feet.
12 feet	= 1 ruth	= 12·35664 American feet.
2,000 ruth	= 1 mile	= 4·68+ American miles.

AUSTRIAN.

12 inches	= 1 foot	= 1·03713 American feet.
6 feet	= 1 klafter.	
4,000 klafter	= 1 mile	= 4·71+ American miles.

SWEDISH.

12 inches	= 1 foot	= 0·97410 American feet.
6 feet	= 1 fathom.	
6,000 fathoms	= 1 mile	= 6·64+ American miles.

CHINESE.

1 chih	=	1·054 American feet.
10 chih	= 1 chang	= 10·54 American feet.
180 chang	= 1 li	= 1,897· American feet.

MEASURES OF AREA.

AMERICAN AND BRITISH.

144 sq. inches	= 1 square foot.		
9 sq. feet	= 1 square yard	= 1,296 sq. in.	
30¼ sq. yards	= 1 perch	= 272¼ sq. ft.	
40 perches	= 1 rood	= 1,210 sq. yds.	= 10,890 sq. ft.
4 roods	= 1 acre	= 160 perches = 4,840 sq. yds.	= 43,560 sq. ft.

METRIC SYSTEM.

1 square millimetre	=	·001550	sq. in.
1 square centimetre	=	·155003	sq. in.
1 square decimetre	=	15·5003	sq. in.
1 square metre or centiare	=	10·764101	sq. ft.
1 square decametre or are	=	·024711	acres.
1 hectare	=	2·47110	acres.
1 square kilometre	=	247·110	acres.
1 square myriametre	=	38·61090	square miles.

MEASURES OF SOLIDS.

AMERICAN AND BRITISH.

1,728 cubic inches = 1 cubic foot.
27 cubic feet = 1 cubic yard.

A cord of wood = 128 cu. ft., or a pile of wood 8 ft. long, 4 ft. wide, and 4 ft. high = 1 cord. A perch of masonry contains 24¾ cu. ft.; but in practice it is taken as 25 cu. ft.

A ton (2,240 lbs.) of Pennsylvania Anthracite, when broken for domestic use, occupies about 42 cu. ft. of space; Bituminous coal, about 46 cu. ft., and coke about 88 cu. ft.

METRIC SYSTEM.

1 millilitre or cu. centimetre	=	·0610254	cu. in.
1 centilitre	=	·610254	cu. in.
1 decilitre	=	6·10254	cu. in.
1 litre, or cu. decimetre	=	61·0254	cu. in.
1 decalitre, or centistere	=	·353156	cu. ft.
1 hectolitre, or decistere	=	3·53156	cu. ft.
1 kilolitre, or cu. metre, or stere	=	35·3156	cu. ft.
1 myriolitre, or decastere	=	353·156	cu. ft.

LIQUID MEASURE (U. S.).

4 gills	= 1 pint,		= 28·876	cu. in.
2 pints	= 1 quart,	= 8 gills,	= 57·75	cu. in.
4 quarts	= 1 gallon,	= 32 gills, = 8 pints	= 231	cu. in.
31½ gallons	= 1 barrel.			
63 gallons	= 1 hogshead.			
2 hogsheads	= 1 pipe.			
2 pipes	= 1 tun.			

DRY MEASURE (U. S.)

2 pints	= 1 quart,	= 67·2006 cu. in.	= 1·16365 liquid qts.
4 quarts	= 1 gallon,	= 268·8025 cu. in.	= 1·16365 liquid gals.
2 gallons	= 1 peck,	= 8 quarts	= 537·6050 cu. in.
4 pecks	= 1 bushel,	= 64 pints,	= 32 quarts, = 8 gals., = 2,150·42 cu. in.

BRITISH IMPERIAL MEASURE, BOTH LIQUID AND DRY.

4 gills	= 1 pint	= 34·6592	cu. in.
2 pints	= 1 quart	= 69·3185	cu. in.
4 quarts	= 1 gallon,	= 277·274	cu. in.
8 quarts	= 1 peck,	= 554·548	cu. in.
4 pecks	= 1 bushel,	= 2,218·192	cu. in.

CONTENTS OF CYLINDERS OR PIPES FOR ONE FOOT IN LENGTH.

The contents of pipes or cylinders in gallons or pounds are to each other as the squares of their diameters. Thus, a pipe 9 ft. in diameter will contain 9 times as much as a 3-foot pipe, or 4 times as much as a 4½-foot pipe.

Diameters in Inches.

Diam. in Inches	Diameter in Decimals of a Foot.	Gallons of 231 cu. in. (U. S. Standard.)	Weight of Water in lbs. in 1 ft. of Length.	Diam. in Inches	Diameter in Decimals of a Foot.	Gallons of 231 cu. in. (U. S. Standard.)	Weight of Water in lbs. in 1 ft. of Length.
¼	·0208	·0025	·02122	5½	·4583	1·234	10·27
½	·0417	·0102	·08488	6	·5	1·469	12·223
¾	·0625	·0230	·19098	6½	·5417	1·724	14·345
1	·0833	·0408	·33952	7	·5833	1·999	16·636
1¼	·1042	·0638	·53050	7½	·625	2·295	19·098
1½	·125	·0918	·76392	8	·6667	2·611	21·729
1¾	·1458	·1249	1·0398	8½	·7083	2·948	24·53
2	·1667	·1632	1·3581	9	·75	3·305	27·501
2¼	·1875	·2066	1·7188	9½	·7917	3·682	30·641
2½	·2083	·2550	2·122	10	·8333	4·080	33·952
2¾	·2292	·3085	2·5676	10½	·875	4·498	37·432
3	·25	·3672	3·0557	11	·9167	4·937	41·082
3½	·2917	·4998	4·1591	11½	·9583	5·396	44·901
4	·3333	·6528	5·4323	12	1·000	5·875	48·891
4½	·375	·8263	6·875				
5	·4167	1·020	8·488				

Diameters in Feet.

1¼	1·25	9·180	76·392	10	10·00	587·6	4889·12
1½	1·50	13·22	110·00	10½	10·50	647·7	5404·24
1¾	1·75	17·99	149·73	11	11·00	710·9	5915·84
2	2·00	23·50	195·56	11½	11·50	777·0	6485·72
2¼	2·25	29·74	247·51	12	......	846·1	7040·00
2½	2·50	36·72	305·57	13	......	992·8	8710·00
2¾	2·75	44·43	369·74	14	......	1152·0	10096·00
3	3·00	52·88	440·00	15	......	1322·0	11000·50
3¼	3·25	65·28	544·37	16	......	1504·0	12516·00
3½	3·50	71·97	631·00	17	......	1698·0	14166·00
3¾	3·75	82·62	687·53	18	......	1904·0	15841·00
4	4·00	94·00	782·24	19	......	2121·0	17691·00
4¼	4·25	106·1	885·40	20	......	2350·0	19556·50
4½	4·50	119·0	990·04	21	......	2591·0	21617·00
4¾	4·75	132·5	1105·71	22	......	2844·0	23663·00
5	5·00	146·9	1222·28	23	......	3108·0	25943·00
5¼	5·25	161·9	1351·06	24	......	3384·0	28160·00
5½	5·50	177·7	1478·96	25	......	3672·0	30557·00
5¾	5·75	194·3	1621·43	26	......	3971·0	34840·00
6	6·00	211·5	1760·00	27	......	4283·0	35641·00
6¼	6·25	229·5	1915·18	28	......	4606·0	40384·00
6½	6·50	248·2	2177·48	29	......	4941·0	41117·00
6¾	6·75	267·7	2233·96	30	......	5288·0	44002·00
7	7·00	287·9	2524·00	31	......	5646·0	46984·00
7½	7·50	330·5	2750·12	32	......	6017·0	50064·00
8	8·00	376·0	3128·96	33	......	6398·0	53242·00
8½	8·50	424·5	3541·60	34	......	6792·0	56664·00
9	9·00	475·9	3960·16	35	......	7197·0	59891·50
9½	9·50	530·2	4422·84	36	......	7614·0	63364·00

MONEY.

UNITED STATES CURRENCY.

10 mills = 1 cent.
10 cents = 1 dime.
10 dimes = 1 dollar.
10 dollars = 1 eagle.

BRITISH MONEY.

4 farthings = 1 penny.
12 pence = 1 shilling.
20 shillings = 1 pound sterling.
21 shillings = 1 Guinea.

VALUE OF FOREIGN COINS IN UNITED STATES CURRENCY.

Crown, Great Britain	$ 1.13
Crown, Spain (half pistole)	1.95
Crown, Germany	1.06
Crown, Sicily	.96
Crown, Denmark, Norway, and Sweden	.27
Copeck, Russia	.00¾
Dollar, Bolivia	.96
Dollar, U. S. of Columbia	.93½
Dollar, Chili, Peru, Ecquador	.93
Dollar, Liberia, Mexico, Sandwich Islands, Canada	1.00
Doubloon, Spain, Mexico	15.65
Doubloon, Central America	14.50 / 15.65
Doubloon, New Granada	15.34
Ducat, Austria, Bohemia, Hamburg, Hanover	2.28
Ducat, Sweden	2.20
Ducat, Denmark	1.81
Franc, France, Belgium, Bulgaria, Italy, Roumania, and Switzerland	.19$\frac{4}{10}$
Florin, Austria, Silesia	.48
Florin, Holland, Netherl'nds, South Germany	$ .38
Florin, (gold) Hanover	1.66
Florin, (silver) Hanover	.56
Florin, Prussia	.55
Gulden, Baden	.40
Guinea, Great Britain	5.11
Groschen, Prussian Poland	.02$\frac{4}{10}$
Imperial, Russia	7.92
Kreutzer, Bavaria	.00⅔
Marc, Germany	.24
Maximillian, Bavaria	3.30
Milrea, Portugal	1.08
Napoleon, France	3.84
Pistole, Rome	3.37
Pistole, Spain	3.90
Peseta or Pistareen, Spain	.20
Piastre, Spain	1.04
Pound, Great Britain	4.87
Rouble, Russia	.75
Shilling, Great Britain	.24
Sovereign, Great Britain	4.87
Sous, France	.01

STRENGTH AND WEIGHT OF MATERIALS.

WOODEN BEAMS.

To find the quiescent breaking-load of a horizontal square or rectangular beam.—Multiply the breadth in inches by the square of depth in inches, divide the product by distance in feet between the supports, and multiply the quotient by the constant given in following table.

To find the quiescent breaking-load of a horizontal cylindrical beam.—Divide the cube of the diameter in inches by the distance between the supports in feet, and multiply the quotient by the constant.

TABLE OF CONSTANTS.

Calculated for seasoned timber. For green timber take one-half of these constants. Safe working-load is one-third of breaking-load.

Woods.	Square or Rectangular.	Round.	Woods.	Square or Rectangular.	Round.
Ash, white	650	383	Locust	600	353
Ash, swamp	400	236	Lignumvitæ	650	383
Ash, black	300	177	Larch	400	236
Balsam, Canada	350	206	Maple	550	324
Beech, white	450	265	Oak, red or black	550	324
Beech, red	550	324	Oak, white	600	353
Birch, black	450	265	Oak, live	600	353
Birch, yellow	450	266	Pine, white	450	265
Cedar, white	250	147	Pine, yellow	500	295
Chestnut	450	265	Pine, pitch	550	324
Elm	350	206	Poplar	550	324
Elm, rock	600	353	Spruce	450	265
Hemlock	400	236	Sycamore	500	295
Hickory	650	383	Willow	350	206
Ironwood	600	353			

EXAMPLES.

Find the quiescent breaking-load, and safe working-load of a yellow pine collar 8 in. square, 12 ft. between legs.

Breaking-load $= \frac{8 \times 8^2}{12} \times 500 = 21{,}335$ lbs. for seasoned, and 10,668 lbs. for green timber.

Safe working-load = 7,111 lbs. for seasoned, and 3,556 lbs. for green timber.

Find the quiescent breaking-load, and the safe working-load of a hemlock collar 10 in. diam., 7 ft. between legs.

Breaking-load $= \frac{10^3}{7} \times 236 = 33{,}715$ lbs. for seasoned timber, and $\frac{33{,}715}{2}$ = 16,857 lbs. for green timber.

Safe working-load $= \frac{33{,}715}{3} = 11{,}238$ lbs. for seasoned, and $\frac{33{,}715}{6}$ or $\frac{11{,}238}{2}$ = 5,619 lbs. for green timber.

Having the length and diameter of a collar to find the diameter of a longer collar to support the same weight.—The strength of collars varies as the cubes of their diameters, and inversely as their lengths.

EXAMPLE.—If a collar 6 ft. long and 8 in. diameter supports a certain weight, what must be the diameter of a collar 12 ft. long to support the same weight?

Ans.—$\sqrt[3]{6} : \sqrt[3]{12} :: 8$ in. : 10+ in.

To find the diameter of a collar when the weight increases in proportion to the length.—Find the required diameter to support the same weight as the short collar. Then the length of the short collar is to the length of the long one as the diameter found to support the original weight is to the required diameter.

EXAMPLE.—If a collar 6 ft. long, 8 in. diam. supports a certain weight, what must be the diameter of a collar 12 ft. long to support twice the weight?

Ans.—$\sqrt[3]{6} : \sqrt[3]{12} :: 8 : (\ )$ or 10+

Then, $6 : 12 :: 10^3 : (\ )^3$, or $\frac{12 \times 1{,}000}{6} = 2{,}000$, and $\sqrt[3]{2{,}000} = 12{\cdot}6$ in.

IRON AND STEEL BEAMS.

Constants for use in calculating strength of iron and steel beams:

Cast-iron	2,000
Wrought-iron	2,200
Steel	5,000

Hard steel will break the same as cast-iron. Soft steel will bend like wrought-iron. The elastic limit of wrought-iron is reached at about 2,200 lbs As it does not break, we use the limit of elasticity.

To find the quiescent breaking-load of a horizontal square or rectangular iron or steel beam.—Multiply the square of its depth in inches by its breadth in inches, and multiply this result by the constant for the material used. Divide by the length in feet between the supports.

EXAMPLE.—Find the quiescent breaking-load of a wrought-iron beam 6 in. square and 12 ft. between supports, and subtract ½ the weight of the beam between its supports. If the load is equally distributed over the beam it will be twice as great as that found by above rule.

Safe working load is ⅓ of breaking-load.

To find the quiescent breaking-load of a cylindrical iron or steel beam.—Find the breaking-load of a square beam the sides of which are equal to the diameter of the round one, and multiply by ·6.

Safe working load is ⅓ of breaking-load. If the load is equally distributed over the beam it will be twice as great.

ROLLED IRON I-BEAMS.

Calculated for loads evenly distributed over beams, and the beams supported at both ends. If the load is concentrated in the center, one-half of the loads in the table must be taken.

Dimensions in inches.			Weight in Pounds per Foot.	Safe Working-Loads in Tons for Spans of				
Depth.	Width of Flange.	Thickness of Web.		10 ft.	15 ft.	20 ft.	25 ft.	30 ft.
15	5 7/8	7/8	83·33	38·88	25·92	19·44	15·55	12·96
15	5 5/8	5/8	66·66	32·35	21·56	16·17	12·94	10·78
15	5	1/2	50·00	24·84	16·56	12·42	9·94	8·28
12	5 5/16	3/4	57·77	21·33	14·22	10·66	8·53	7·11
12	4 11/16	1/2	41·67	16·65	11·10	8·33	6·66	5·56
10 1/2	5	1/2	45·00	16·38	10·92	8·19	6·55	5·46
10 1/2	4 7/16	1/2	35·00	12·06	8·04	6·03	4·82	4·02
10 1/2	4 1/8	7/16	30·00	10·44	6 96	5·22	4·18	3·48
9	4 7/16	9/16	30·00	8·64	5·76	4·32	3·55	2·88
9	4 1/4	7/16	28·33	8·46	5·64	4·23	3·38	2·82
9	4 1/8	3/8	23·33	7·11	4·74	3·56	2·84	2·37
8	4 3/16	1/2	26·67	6·93	4·62	3·47	2·77	2·31
8	4	5/16	21·67	6·12	4·08	3·06	2·45	1·98
7	3 9/16	7/16	21·67	5·13	3·42	2·57	2·05	1·71
7	3 7/16	5/16	18·33	4·50	3·00	2·25	1·80	1·50
6	3 7/16	5/16	16·67	3·51	2.34	1·76	1·40	1·17
6	3 3/8	1/4	13·33	2·88	1·92	1·44	1·15	0·96
5	3	5/16	13·33	2·25	1·50	1·13	0·90	
5	2 3/4	3/16	10 00	1·73	1·15	0·86	0·69	
4	2 1/2	7/16	10·00	1·26	0·84	0·63	0·50	
4	2 1/4	5/16	8·00	1·17	0·78	0·59	0·47	
4	2 1/8	3/16	7·67	0·72	0·48	0·36	0·29	

PILLARS OR PROPS.

To find the crushing-load of either square or rectangular wooden pillars or props.—Call one side of the square or the least side of the rectangle the breadth. Divide the square of the length in inches by the square of the breadth in inches, multiply the quotient by ·004, add 1 to the product, and divide the constant in the following table by the result. Then multiply this quotient by the number of square inches in the end of the prop.

$$\left.\begin{array}{r}\text{Or, breaking-load in lbs.}\\ \text{per sq. in. of area}\end{array}\right\} = \text{Constant} \div 1 + \left\{ \frac{L^2}{B^2} \times \cdot 004 \right\}$$

When L = Length in inches, and B = Breadth in inches.

TABLE OF CRUSHING-LOADS OF AMERICAN WOODS

in small blocks of 1 sq. in. area. These are for well-seasoned wood. For green timber take ½ of the constants or crushing-strength. Safe working-load = ⅓ of crushing-load.

Wood.	Crushing-Load in Lbs. per Sq. In.	Wood.	Crushing-Load in Lbs. per Sq. In.
Ash	6,800	Maple, sugar, black	8,000
Beech	7,000	Maple, white, red	6,800
Birch	8,000	Oak, white, red, black	7,000
Cedar, red	6,000	Oak, scrub, basket	6,000
Cedar, white	4,400	Oak, chestnut, live	7,500
Chestnut	5,300	Oak, pin	6,500
Hemlock	5,300	Pine, white	5,400
Hickory	8,000	Pine, pitch	5,000
Linden	5,000	Pine, Georgia	8,500
Locust, black, yellow	9,800	Poplar	5,000
Locust, honey	7,000	Spruce, black	5,700
Maple, broad-leafed		Spruce, white	4,500
Oregon	5,300	Willow	4,400

Example.—What is the breaking-load of a well-seasoned hemlock post 10 in. by 8 in. and 12 ft. long?

Ans.—$5{,}300 \div 1 + \left\{\frac{144^2}{8^2} \times {\cdot}004\right\} = 2308{\cdot}4$ lbs. per sq. inch of area. $2308{\cdot}4 \times 80 = 184{,}672$ lbs.

To find the breaking-load of a cylindrical wooden prop.—Find the breaking-load of a square prop whose ends are equal in area to those of the cylindrical one, and proceed according to foregoing rule.

Example.—What is the safe working-load for a hemlock mine-prop 10 in. diameter, 10 ft. long?

Ans.—The area of the end of the prop = 78·54 sq. in. A square of equal area will have sides = to $\sqrt{78{\cdot}54} = 8{\cdot}86+$ in.

Then, $5{,}300 \div 1 + \left\{\frac{120^2}{8{\cdot}86^2} \times {\cdot}004\right\} = 3{,}058{\cdot}3$ lbs. per each square inch of area. And $3058{\cdot}3 \times 78{\cdot}54 = 240{,}198$ lbs. This is the crushing-strength of a similar prop of seasoned timber, but as mine-timber is used in its green state we take ½ of 240,198 lbs. or 120,099 lbs. as the crushing-load of the prop in question. Then, the safe working-load is ⅓ of this, or 40,033 lbs.

SAFE WORKING-LOAD FOR HOLLOW CAST-IRON PILLARS.

Thickness of Metal.	External Diameter.	Length of Pillar.				
		8 ft.	10 ft.	12 ft.	14 ft.	16 ft.
	Inches.	Tons.	Tons.	Tons.	Tons.	Tons.
	3	4·0	3·2	2·3	1·8	1·4
	3½	5·9	5·1	3·6	2·7	2·3
	4	8·1	6·1	4·7	3·6	3·4
½ in.	4½	10 6	8·1	6·5	5·0	4·4
	5	13·3	10·4	8·3	6·7	5·4
	5½	15·3	12·9	10·5	8·5	7·0
	6	19·0	15·5	12·7	9·5	8·7
	3	4·7	3·5	2·6	2·0	1·6
	3½	7·1	5·3	4·2	3·2	2·5
	4	9·2	7·3	5·6	4·4	3·9
	4½	12·8	9·9	7·7	6·1	5·5
⅝ in.	5	16·1	12·7	9·1	8·1	7·0
	5½	18·7	15·7	12·8	10·4	8·8
	6	23·2	19·0	15·6	12·8	10·6
	6½	86 9	22·4	18·7	15·2	13·0
	7	30·7	26·0	21·9	18·5	15·6
	3	5·4	3·8	2·8	2·2	1·7
	3½	8·1	6·2	4·4	3·5	2·6
	4	11·3	8·5	6·5	4·8	3·8
	4½	14·9	11·5	8·9	7·2	6·0
¾ in.	5	18·8	14·8	11·7	9·0	7·7
	5½	21·8	18·4	14·9	12·1	10·2
	6	27·2	22·3	18 3	15·0	12·5
	6½	31·6	26·3	21·9	17·8	15 3
	7	36·1	30·6	25·8	21·7	18·4
	4	13·9	10·4	8·0	6·4	4·8
	4½	18·5	14·3	11·1	8·8	7 1
	5	23·6	18·6	14·8	11·9	9·6
	5½	27·6	23·2	18·9	15·3	12·7
	6	34·5	28·3	23·2	19·1	15·9
1 in.	6½	40·3	33·6	28·0	22·8	19·6
	7	46·2	39·1	33·0	27·8	23·6
	7½	52·2	44·9	38·3	32·6	27·9
	8	58·3	50·7	43·8	37·7	32·5
	8½	64 3	56·5	49·4	42·9	37·3
	9	70·5	62·7	55·3	48·1	42·3

TABLE TO SHOW THE WEIGHT OR PRESSURE A COLUMN OF CAST-IRON WILL SUSTAIN WITH SAFETY.

Length or Height in feet.	8	10	12	14	16	18	20	22	24
Diameter. Inches.	Weight in cwt.	Weight in cwt.	Weight in cwt.	Weight in cwt.	Weight in cwt.	Weight in cwt.	Weight in cwt.	Weight in cwt.	Weight in cwt.
2½	91	77	65	55	47	40	34	29	25
3	145	128	111	97	84	73	64	56	49
3½	214	191	172	156	135	119	106	94	83
4	288	266	242	220	198	178	160	144	130
4½	379	354	327	301	275	251	229	208	189
5	479	452	427	394	365	337	310	285	262
6	573	550	525	497	469	440	413	386	360
7	989	959	924	887	848	808	765	725	686
8	1289	1259	1224	1185	1142	1097	1052	1005	959
9	1672	1640	1603	1561	1515	1467	1416	1364	1311
10	2077	2045	2007	1964	1916	1865	1811	1755	1697
11	2520	2490	2450	2410	2358	2305	2248	2189	2127
12	3020	2970	2930	2900	2830	2780	2730	2670	2600

GREATEST SAFE LOAD, PER SUPERFICIAL FOOT.

On Granite piers is	40	tons.
Portland stone piers	13	"
Bath stone piers	8	"
Brickwork in cement	3	"
Rubble masonry	2	"
Lime concrete foundation	2½	"

The height of brick or stone piers should never exceed 12 times their least thickness at base.

SHAFTING.

Shafts are subject to two forces—transverse strain and torsion.

When the machines to be driven are below the shaft, there is a transverse strain on the shaft, due to the weight of the shaft itself, of the pulley and tension of the belt. Sometimes the power is taken off horizontally on one side, in which case the tension of the belt produces a horizontal transverse strain, while the weight of the pulley acts with the weight of the shaft to produce a vertical transverse strain. When the machinery to be driven is placed on the floor above the shaft, the tension of the belt produces a transverse strain in opposite direction to that due to the weight of the shaft and pulley. The transverse strain diminishes as the velocity of the shaft increases.

The torsional strength of shafts or their resistance to breaking by twisting, is proportional to the cube of their diameter. Their stiffness or resistance to bending is proportional to the fourth power of their diameters, and varies inversely in proportion to their load and also to the cube of the length of their spans.

STRENGTH OF WROUGHT-IRON SHAFTING.

D = Diameter of shaft in inches.
H = Indicated horse-power to be transmitted.
N = Number of revolutions per minute.

In crank-shaft and prime movers: $D = \sqrt[3]{\frac{83\ H}{N}}$; $H = \frac{D^3\ N}{83}$

For ordinary shafting: $D = \sqrt[3]{\frac{65\ H}{N}}$; $H = \frac{D^3\ N}{65}$

LENGTH OF SHAFTING TO RESIST TORSION.

L = Length of lever in inches, or radius of wheel at which force is applied.
F = Force applied in pounds.
D = Diameter of shaft in inches.
K = 1,700 for wrought-iron ; 3,200 for cast-steel ; 1,500 for cast-iron.

$$D = \sqrt[3]{\frac{F\ L}{K}}; \qquad F = \frac{D^3\ K}{L}$$

Example.—Required to find the diameter of a wrought-iron shaft for a drum having 2 tons pulling on it at 30-inch radius. L = 30; F = 2 × 2,240 = 4,480; K = 1,700; then,

$$D = \sqrt[3]{\frac{30 \times 4{,}480}{1{,}700}} = 4 \cdot 3 \text{ inches.}$$

SPECIFIC GRAVITY, WEIGHT, AND PROPERTIES OF MATERIALS, &C.

The specific gravity of a body is its weight in proportion to an equal bulk of pure water, at a standard temperature. The standard temperature is 62° Fahr. = 16·670° Cent. A cubic inch of water weighs 252·456 Troy grains, the temperature being 62° Fahr., and the height of the barometrical column, 30 inches; and 7,000 Troy grains are equivalent to one pound Avoirdupois. Thence it follows that a cubic foot of water would weigh 997·136 ounces.

To find the specific gravity of a solid heavier than water.—Weigh the body both in air and in water; to the weight in air annex 3 ciphers, and divide by the difference of weight.

To find the specific gravity of a solid lighter than water.—Attach to it another body heavy enough to sink it, weigh severally the compound mass, and the heavier body in water, and say: As the difference of weights lost in water is to the weight of the given body in air, so is the specific gravity of water to that of the given body.

To find the specific gravity of a fluid.—Weigh both in and out of the fluid a solid (insoluble) of known specific gravity; then say: As the weight of the solid to that lost in the fluid, so is the specific gravity of the former to that of the latter.

The weight of a cubic foot of water at a temperature of 62° is 1,000 ounces Avoirdupois, and the specific gravity of a body, water being 1,000, shows the weight of a cubic foot of that body in ounces Avoirdupois. Then, if the magnitude of the body be known, its weight can be computed, or if its weight be known, its magnitude can be calculated, provided we know its specific gravity; or of the magnitude, weight, and specific gravity, any two being known, the third may be found.

To find the magnitude of a body from its weight.—Say, as the specific gravity is to its weight in ounces, so is one cubic foot to its magnitude in feet.

To find the weight of a body from its magnitude.—Say, as one cubic foot is to its magnitude in feet, so is its specific gravity to its weight in ounces.

SPECIFIC GRAVITY OF SUBSTANCES.

NOTE—The specific gravity of any substance is equal to its weight in grammes per cubic centimetre. (See table of metric weights and measures.)

Substance.	Average Specific Gravity.	Average Weight per Cu. Ft. in Lbs.
Air, atmospheric; at 60° Fahr. under pressure of 1 atmosphere, or 14·7 lbs. per sq. in.	·00123	·0765
Alcohol, pure	·793	49·43
Alcohol, of commerce	·834	52·10
Aluminum	2·6	162·00
Anthracite coal	1·5	93·50
Anthracite increases about 75 per cent. in bulk when broken to any market size. A ton loose averages from 40 to 43 cu. ft.		
Asphaltum	1·4	87·3
Brass, cast	8·1	504·0
Brass, rolled	8·4	524·0
Bronze, gun-metal	8·5	529·0
Brick, best pressed		150·0

Substance.	Average Specific Gravity.	Average Weight per Cu. Ft. in Lbs.
Brick, common hard		125·0
Carbonic acid gas	·00187	·1147
Clay, dry, in lumps loose		63·00
Clay, potters', dry	1·9	119·00
Coke, loose, of good coal		27·5
A heaped bushel, loose, weighs from 35 to 42 lbs. A ton occupies 80 to 97 cu. ft.		
Coal, Bituminous	1·35	84·0
Coal, Bituminous, broken, loose		50·0
Coal, Bituminous, moderately shaken		54·0
A heaped bushel, loose, weighs about 74 lbs., and a ton occupies from 43 to 48 cu. ft. Bituminous coal, when broken, occupies 75 per cent. more space than in the solid.		
Copper, cast	8·7	542·0
Copper, rolled	8·9	555·0
Cork,	·25	15·6
Earth, common loam, perfectly dry, loose		76·0
Earth, common loam, perfectly dry, shaken		87·0
Earth, common loam, perfectly dry, moderately packed		95·0
Earth, common loam, slightly moist, loose		78·0
Earth, common loam, more moist, loose		80·0
Earth, common loam, more moist, shaken		90·0
Earth, common loam, more moist, packed		96·0
Earth, common loam, as a soft flowing mud		108·0
Earth, common loam, as a soft mud packed		115·0
Gypsum (Plaster of Paris)	2·27	141·6
Gypsum, in irregular lumps		82·0
Gypsum, ground, loose		56·0
Gypsum, ground, well shaken.		64·0
Gypsum, calcined loose		56·0
Gravel		98·0
Gold, cast, pure or 24 carat	19·26	1204·0
Gold, native, pure or 19·32 carat	19·32	1206·0
Gutta Percha	·98	61·1
Hydrogen Gas, 14½ times lighter than air and 16 times lighter than oxygen		·00527
Iron, cast	7·15	450
Iron, wrought	7·77	485
Iron, rolled bars	7·65	480
Iron, sheet		485
Ice	·92	57·4
Lead	11·38	710
Lime, quick	1·9	95
Lime, quick, ground, loose, per struck bushel, 66 lbs.		
Lime, quick, ground, well-shaken, per struck bu., 86 lbs.		
Mercury, at 32° F.	13·62	849
Mercury, at 60° F.	13·58	846
Mercury, at 212° F.	13·38	836
Nitrogen Gas, $\frac{1}{38}$ part lighter than air		·0744
Oils, whale, olive	·92	57·3
Oxygen Gas, $\frac{1}{10}$ part heavier than air	·00136	·0846
Petroleum	·878	54·8
Powder	1·00	62·3
Rosin	1·1	68·6
Slate	2·8	175·0
Silver	10·5	655·0
Steel	7·8	490·0
Sulphur	2·0	125·0
Tallow	·94	58·6
Tin, cast	7·35	459·0
Water, pure rain or distilled, at 32° F., Barom. 30 in.		62·417
Water, pure rain or distilled, at 62° F., Barom. 30 in.	1·00	62·355
Water, pure rain or distilled, at 212° F., Barom. 30 in.		59·7
Water, sea, average	1·03	64·08
Zinc	7·00	437·5

WEIGHT OF CAST-IRON.

To find the approximate weight of a casting, multiply the weight of the pattern by 20. Copper is 1/8 heavier; Lead, 3/5 heavier; Brass, 1/7 heavier.

Thickness or Diameter in inches.	Weight of a Square Foot in lbs.	Weight of a Square Bar 1 ft. long in lbs.	Weight of a Round Bar 1 ft. long in lbs.	Thickness or Diameter in inches.	Weight of a Square Foot in lbs.	Weight of a Square Bar 1 ft. long in lbs.	Weight of a Round Bar 1 ft. long in lbs.
1/4	9·375	·195	·154	4 1/2	168·7	63·33	49·71
3/8	14·06	·440	·346	4 5/8	173·4	66·86	52·52
1/2	18·75	·781	·610	4 3/4	178·1	70·52	55·39
5/8	23·44	1·221	·959	4 7/8	182·8	74·27	58·34
3/4	28·12	1·758	1·381	5	187·5	78·12	61·37
7/8	32·81	2·393	1·880	5 1/4	196·9	86·14	67·65
1	37·50	3·125	2·455	5 1/2	206·2	94·54	74·26
1 1/8	42·19	3·955	3·107	5 3/4	215·6	103·3	81·16
1 1/4	46·87	4·883	3·835	6	225·0	112·5	88·36
1 3/8	51·57	5·909	4·640	6 1/4	234·4	122·1	95·89
1 1/2	56·26	7·033	5·523	6 1/2	243·8	132·0	103·7
1 5/8	60·94	8·253	6·484	6 3/4	253·1	142·4	111·9
1 3/4	65·63	9·572	7·518	7	262·5	153·2	120·2
1 7/8	70·32	10·99	8·630	7 1/4	271·9	164·2	129·0
2	75·01	12·50	9·821	7 1/2	281·3	175·8	138·1
2 1/8	79·70	14·11	11·09	7 3/4	290·7	187·7	147·4
2 1/4	84·40	15·83	12·43	8	300·0	200·1	157·0
2 3/8	89·07	17·63	13·85	8 1/4	309·4	212·7	167·0
2 1/2	93·75	19·54	15·34	8 1/2	318·8	225·8	177·3
2 5/8	98·44	21·54	16·56	8 3/4	328·2	239·3	187·9
2 3/4	103·2	23·64	18·56	9	337·4	253·1	198·8
2 7/8	107·8	25·84	20·29	9 1/4	346·8	267·4	210·0
3	112·6	28·13	22·10	9 1/2	356·2	282·1	221·5
3 1/8	117·3	30·52	23·97	9 3/4	365·6	297·0	233·3
3 1/4	121·8	33·01	25·93	10	375·0	312·5	245·5
3 3/8	126·5	35·60	27·95	10 1/4	384·4	328·4	257·8
3 1/2	131·2	38·28	30·07	10 1/2	393·7	344·5	270·6
3 5/8	135·9	41·07	32·25	10 3/4	403·1	361·2	283·7
3 3/4	140 6	43·95	34·51	11	412·5	378·2	297·0
3 7/8	145·3	46·93	36·85	11 1/4	421·9	395·5	310·6
4	150·0	50·01	39·27	11 1/2	431·2	413·3	324·6
4 1/8	154·7	53·18	41·77	11 3/4	440·6	431·4	338·8
4 1/4	159·3	56·46	44·33	12	450·0	450·0	353·4
4 3/8	164·0	59·82	46·99				

WEIGHT OF A SUPERFICIAL FOOT OF PLATES, DIFFERENT METALS, IN POUNDS.

Thickness. Inches.	Iron.	Brass.	Copper.	Lead.	Zinc.	Thickness.
1/16	2·5	2·7	2·9	3·7	2·3	·0625 inches = 16 B.W.G.
1/8	5·0	5·5	5·8	7·4	4·7	·125 " = 11 "
3/16	7·5	8·2	8·7	11·1	7·0	·1875 " = 7 "
1/4	10·0	11·0	11·6	14·8	9·4	·25 " = 4 "
5/16	12·5	13·7	14·5	18·5	11·7	·3125 " = 1 "
3/8	15·0	16·4	17·2	22·2	14·0	·375
7/16	17·5	19·2	20·0	25·9	16·4	·4375
1/2	20·0	21·9	22·9	29·5	18·7	·5
9/16	22·5	24·6	25·7	33·2	21·1	·5625
5/8	25·0	27·4	28·6	36·9	23·4	·625
11/16	27·5	30·1	31·4	40·6	25·7	·6875
3/4	30·0	32·9	34·3	44·3	28·1	·75
13/16	32·5	35·6	37·2	48·0	30·4	·8125
7/8	35·0	38·3	40·0	51·7	32·8	·875
15/16	37·5	41·2	42·9	55·4	35·1	·9375
1	40·0	43·9	45·8	59·1	37·5	1·000

WEIGHT OF CAST-IRON PIPE PER FOOT IN POUNDS.

These weights are for plain pipe. For hautboy pipe add 8 inches in length for each joint when using this table. For copper add ⅛; for lead, ⅜; for welded iron add $\frac{1}{15}$, or multiply by 1·0667.

Diameter of Bore in Inches.	Thickness of Pipe in Inches.												
	¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1¾	2
1	3·07	5·07	7·38										
1¼	3·69	6·00	8·61										
1½	4·30	6·92	9·84										
1¾	4·92	7·84	11·1										
2	5·53	8·76	12·3	16·2									
2¼	6·15	9·69	13·5	17·7									
2½	6·76	10·6	14·8	19·2	24·0								
2¾	7·37	11·5	16·0	20·8	25·9								
3	7·98	12·5	17·2	22·3	27·7	33·4							
3½	9·21	14·3	19·7	25·4	31·4	37·7							
4	10·3	16·1	22·2	28·5	35·1	42·0							
4½	11·7	18·0	24·6	31·5	38·8	46·3							
5	12·9	19·8	27·1	34·6	42·5	50·6							
5½	14·2	21·7	29·5	37·7	46·1	54·9							
6	15·4	23·5	32·0	40·8	49·8	59·2	68·9						
6½	16·6	25·4	34·5	43·8	53·5	63·5	73·8	84·4					
7	17·8	27·2	36·9	46·9	57·2	67·8	78·7	89·4					
7½	19·1	29·1	39·4	50·0	60·9	72·1	83·7	95·5	108·0				
8	20·3	30·9	41·8	53·1	64·6	76·4	88·6	101	114	127			
8½	21·5	32·8	44·3	56·1	68·3	80·7	93·5	107	120	134	148		
9	22·8	34·6	46·8	59·2	72·0	85·1	98·4	112	126	140	155		
9½	24·0	36·4	49·2	62·3	75·7	89·3	103	118	132	147	163		
10	25·1	38·3	51·7	65·3	79·4	93·6	108	123	138	164	170	202	
11	27·6	42·0	56·6	71·5	86·7	102	118	134	151	168	185	220	
12	30·0	45·7	61·5	77·7	94·1	111	128	145	163	181	199	237	275
13	32·5	49·4	66·4	83·8	102	120	138	156	175	195	214	254	294
14	35·0	53·1	71·4	89·4	109	128	148	168	188	208	229	271	314
15	37·4	56·7	76·3	96·1	116	137	158	179	200	222	244	289	334
16	39·1	60·4	81·2	102	124	145	167	190	212	235	258	306	353
17	42.3	64·1	86·1	108	131	154	177	201	225	249	273	323	373
18	44·8	67·8	91·0	115	139	163	187	212	237	262	288	340	393
19	47·3	71·5	96·0	121	146	171	197	223	249	276	303	357	412
20	49·7	75·2	101	127	153	180	207	234	261	289	317	375	432
21	52·2	78·9	106	133	161	188	217	245	274	303	332	392	452
22	54·6	82·6	111	139	168	196	227	256	286	316	347	409	471
23	57·1	86·3	116	145	175	206	236	267	298	330	362	426	491
24	59·6	89·9	121	152	183	214	246	278	311	343	375	444	511
25	62·0	93·6	126	158	190	223	256	289	323	357	391	461	531
26	64·5	97·3	131	164	198	231	266	300	335	370	406	478	550
27	66·9	101	135	170	205	240	276	311	348	384	421	495	570
28	69·4	105	140	176	212	249	286	323	360	397	436	512	590
29	71·8	109	145	182	220	257	295	334	372	411	450	530	609
30	74·2	112	150	188	227	266	305	345	384	424	465	547	629

SHEET-IRON—AMERICAN MAKE.

No.	Lbs. per Square Foot.	No.	Lbs. per Square Foot.	No.	Lbs. per Square Foot.	No.	Lbs. per Square Foot.
1	12·50	8	6·86	15	2·81	22	1·25
2	12·00	9	6·24	16	2·50	23	1·12
3	11·00	10	5·62	17	2·18	24	1·00
4	10·00	11	5·00	18	1·86	25	·90
5	8·75	12	4·38	19	1·70	26	·80
6	8·12	13	3·75	20	1·54	27	·72
7	7·50	14	3·12	21	1·40	28	·64

WEIGHT OF WROUGHT-IRON.

The following table is for wrought-iron. Add 1% for weight of steel.
Multiply by ·95 for weight of cast-iron.
Multiply by 1·02 for weight of steel.
Multiply by 1·16 for weight of copper.
Multiply by 1·09 for weight of brass.
Multiply by 1·48 for weight of lead.

Thickness or Diameter in Inches.	Weight of a Square Foot. Lbs.	Weight of a Square Bar 1 Foot Long. Lbs.	Weight of a Round Bar 1 Foot Long. Lbs.	Thickness or Diameter in Inches.	Weight of a Square Foot. Lbs.	Weight of a Square Bar 1 Foot Long. Lbs.	Weight of a Round Bar 1 Foot Long. Lbs.
1/8	5·052	·0526	·0414	4 3/8	176·8	64·47	50·63
1/4	10·10	·2105	·1653	4 1/2	181·9	68·20	53·57
3/8	15·16	·4736	·3720	4 5/8	186·9	72·05	56·59
1/2	20·21	·8420	·6613	4 3/4	192·0	75·99	59·69
5/8	25·26	1·316	1·033	4 7/8	197.0	80·05	62·87
3/4	30·31	1·895	1·488	5	202·1	84·20	66·13
7/8	35·37	2·579	2·025	5 1/4	212·2	92·83	72·91
1	40·42	3·368	2·645	5 1/2	222·3	101·9	80·02
1 1/8	45·47	4·263	3·348	5 3/4	232·4	111·4	87·46
1 1/4	50·52	5·263	4·133	6	242·5	121·3	95·23
1 3/8	55·57	6·368	5·001	6 1/4	252·6	131·6	103·3
1 1/2	60·63	7·578	5·952	6 1/2	262·7	142·3	111·8
1 5/8	65·68	8·893	6·985	6 3/4	272·8	153·5	120·5
1 3/4	70·73	10·31	8·101	7	282·9	165·0	129·6
1 7/8	75·78	11·84	9·300	7 1/4	293·0	177·0	139·0
2	80·83	13·47	10·58	7 1/2	303·1	189·5	148·8
2 1/8	85·89	15·21	11·95	7 3/4	313·2	202·3	158·9
2 1/4	90·94	17·05	13·39	8	323·3	215·6	169·3
2 3/8	95·99	19·00	14·92	8 1/4	333·4	229·3	180·1
2 1/2	101·0	21·05	16·53	8 1/2	343·5	243·4	191·1
2 5/8	106·1	23·21	18·23	8 3/4	353·6	247·9	202·5
2 3/4	111·2	25·47	20·01	9	363·8	272·8	214·3
2 7/8	116·2	27·84	21·87	9 1/4	373·9	288·2	226·3
3	121·3	30·31	23·81	9 1/2	384·0	304·0	238·7
3 1/8	126·3	32·89	25·83	9 3/4	394·1	320·2	251·5
3 1/4	131·4	35·57	27·94	10	404·2	336·8	264·5
3 3/8	136·4	38·37	30·13	10 1/4	414·3	353·9	277·9
3 1/2	141·5	41·26	32·41	10 1/2	424·4	371·3	291·6
3 5/8	146·5	44·26	34·76	10 3/4	434·5	389·2	305·7
3 3/4	151·6	47·37	37·20	11	444·6	407·5	320·1
3 7/8	156·6	50·57	39·72	11 1/4	454·7	426·3	334·8
4	161·7	53·89	42·33	11 1/2	464·8	445·4	349·8
4 1/8	166·7	57·31	45·01	11 3/4	474·9	465·0	365·2
4 1/4	171·8	60·84	47·78	12	485	485	380·9

WEIGHT OF WROUGHT-IRON BOLT-HEADS, NUTS, AND WASHERS.

Diameter of Bolt. Inch.	Hexagon Heads and Nuts. Per Pair.	Square Heads and Nuts. Per Pair.	Round Washers. Per Pair.
0 1/4	20 to a lb.	16 to a lb.	20 to a lb.
0 3/8	10 "	8 1/3 "	10 "
0 1/2	5 "	4 1/6 "	5 "
0 5/8	2 3/4 "	2 1/2 "	3 "
0 3/4	2 "	0·56 lb.	0·63 lb.
0 7/8	0·77 lb.	0·88 "	0·77 "
1	1·25 "	1·31 "	1·25 "
1 1/8	1·75 "	2·10 "	1·75 "
1 1/4	2·13 "	2·56 "	2·25 "
1 3/8	3 "	3·60 "	3·25 "
1 1/2	3·75 "	4·42 "	4·25 "
1 5/8	4·75 "	5·70 "	5·25 "
1 3/4	5·75 "	7 "	6·50 "
1 7/8	7·27 "	8·72 "	8 "
2	8·75 "	10·50 "	9·60 "

TABLE OF THE WEIGHT, IN POUNDS, OF ONE LINEAL FOOT OF WROUGHT-IRON—FLAT.

Size. Ins.		In.	Weight. Lbs.
1	by	¼	0·85
1¼	by	¼	1·06
1½	by	¼	1·27
1¾	by	¼	1·48
2	by	¼	1·69
2¼	by	¼	1·90
2½	by	¼	2·11
2¾	by	¼	2·32
3	by	¼	2·53
3¼	by	¼	2·75
3½	by	¼	2·96
3¾	by	¼	3·17
4	by	¼	3·38
4¼	by	¼	3·59
4½	by	¼	3·80
4¾	by	¼	4 01
5	by	¼	4·22
5¼	by	¼	4·44
5½	by	¼	4·65
5¾	by	¼	4·86
6	by	¼	5·07
1	by	⅜	1·27
1¼	by	⅜	1·58
1½	by	⅜	1·90
1¾	by	⅜	2·22
2	by	⅜	2·53
2¼	by	⅜	2·85
2½	by	⅜	3·17
2¾	by	⅜	3·49
3	by	⅜	3·80
3¼	by	⅜	4·12
3½	by	⅜	4·44
3¾	by	⅜	4·75
4	by	⅜	5·07
4¼	by	⅜	5·39
4½	by	⅜	5·70
4¾	by	⅜	6·02
5	by	⅜	6·33
5¼	by	⅜	6·65
5½	by	⅜	6·97
5¾	by	⅜	7·29
6	by	⅜	7·60
1	by	½	1·69
1¼	by	½	2·11
1½	by	½	2·53
1¾	by	½	2·96
2	by	½	3·38
2¼	by	½	3·80
2½	by	½	4·22
2¾	by	½	4·65
3	by	½	5·07
3¼	by	½	5·49
3½	by	½	5·92
3¾	by	½	6·33
4	by	½	6·76
4¼	by	½	7·18
4½	by	½	7·60
4¾	by	½	8·03
5	by	½	8·45
5¼	by	½	8·87
5½	by	½	9·30
5¾	by	½	9·72
6	by	½	10·14
1	by	⅝	2·11
1¼	by	⅝	2·64
1½	by	⅝	3·17
1¾	by	⅝	3·70
2	by	⅝	4·22
2¼	by	⅝	4·75
2½	by	⅝	5·28
2¾	by	⅝	5·81
3	by	⅝	6·33
3¼	by	⅝	6·87
3½	by	⅝	7·39
3¾	by	⅝	7·92
4	by	⅝	8·45
4¼	by	⅝	8·98
4½	by	⅝	9·51
4¾	by	⅝	10·03
5	by	⅝	10·56
5¼	by	⅝	11·09
5½	by	⅝	11·62
5¾	by	⅝	12·15
6	by	⅝	12·67
1	by	¾	2·53
1¼	by	¾	3·17
1½	by	¾	3·80
1¾	by	¾	4·44
2	by	¾	5·07
2¼	by	¾	5·70
2½	by	¾	6·33
2¾	by	¾	6·97
3	by	¾	7·60
3¼	by	¾	8·24
3½	by	¾	8·87
3¾	by	¾	9·51
4	by	¾	10·14
4¼	by	¾	10·77
4½	by	¾	11·41
4¾	by	¾	12·04
5	by	¾	12·67
5¼	by	¾	13·31
5½	by	¾	13·94
5¾	by	¾	14·57
6	by	¾	15·21
1½	by	1	5·07
2	by	1	6·76
3	by	1	10·14
4	by	1	13·52
5	by	1	16·90
6	by	1	20·28
7	by	1	23·66

Multiply by ·95 for weight of cast-iron; by 1·02 for weight of steel; by 1·16 for copper; by 1·09 for brass; by 1·48 for lead.

TABLE OF THE WEIGHT OF LEAD PIPE PER YARD.

From ¼ to 4½ inches Diameter.

Diameter.	Extra Light.		Light.		Medium.		Strong.		Extra Strong.	
Inches.	lbs.	oz.	lbs.	oz.	lbs.	oz.	lbs.	oz.	lbs.	oz.
¼	—	—	—	—	3	—	4	—	—	—
½	—	—	3	—	4	—	5	—	6	4
⅝	—	—	5	—	6	8	7	8	8	4
¾	5	—	6	4	8	—	9	12	10	8
1	6	8	8	5	10	5	12	4	—	—
1¼	8	5	9	12	11	—	12	8	14	10
1½	9	—	13	—	15	8	19	—	—	—
1¾	—	—	—	—	16	—	20	—	—	—
2	—	—	16	12	20	—	23	—	—	—
2½	—	—	25	—	30	—	35	—	—	—
3	—	—	30	—	35	—	44	—	—	—
3½	—	—	—	—	45	—	54	—	70	—
4 waste.	—	—	—	—	21	—	26	—	—	—
4½ "	—	—	—	—	24	—	29	—	—	—

WEIGHT OF 100 BOLTS OF THE ENUMERATED SIZES, WITH SQUARE HEADS AND NUTS.

Lengths.	Diameters.							
	¼ in.	5/16 in.	⅜ in.	7/16 in.	½ in.	⅝ in.	¾ in.	⅞ in.
Ins.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1½	4·16	7·59	10·62	15·94	23·87	39·31	....	....
1¾	4·22	7·87	11·72	16·90	25·06	41·48	....	....
2	4·75	8·56	12·38	18·25	26·44	45·69	73·62	....
2¼	5·34	9·12	12·90	19·38	28·62	49·50	76·	....
2½	5·97	9·59	14·69	20·69	29·50	51·25	79·75	....
2¾	6·50	10·44	16·47	21·50	31·16	53·	83·	....
3	.....	11·78	17·88	22·38	32·44	56·	85·38	127·25
3½	.....	11·81	18·94	26·19	39·75	63·12	93·44	140·56
4	.....	......	20·59	28·87	42·50	74·87	108·12	148·37
4½	.....	......	21·69	29·87	44·87	79·62	113·12	158·76
5	.....	......	23·62	32·31	48·81	83·	122·	167·25
5½	.....	......	25·81	34·44	51·38	87·88	128·62	174·88
6	.....	......	26·87	36·62	53·31	92·38	131·75	204·25
6½	.....	......	......	......	56·87	96·88	139·56	214·69
7	.....	......	......	......	59·12	99·87	145·50	228·44
7½	.....	......	......	......	61·87	105·75	150·88	235·31
8	.....	......	......	......	64·44	109·50	157·12	239·88
9	.....	......	......	......	70·50	118·12	169·62	258·12
10	.....	......	......	......	77·	128·13	184·	276·18
11	.....	......	......	......	82·88	136·19	195·13	295·69
12	.....	......	......	......	86·37	144·87	209·75	311·94
13	.....	......	......	......	92·	155·50	219·37	335·81
14	.....	......	......	......	97·75	163·58	237·50	351·88
15	.....	......	......	......	103·25	170·75	249·06	391·75

IRON REQUIRED FOR ONE MILE OF TRACK.

TONS OF IRON.

Rule.—*To find the number of tons of rails to the mile, divide the weight per yard by 7, and multiply by 11. Thus, for 56-pound rail, divide 56 by 7, equal 8, multiplied by 11 equal 88 tons, for one mile of single track.*

Weight of Rail per Yard.	Tons per mile.		Weight of Rail per Yard.	Tons per mile.	
Lbs.	Tons.	Lbs.	Lbs.	Tons.	Lbs.
12	18	1,920	45	70	1,600
14	22		48	75	960
16	25	320	50	78	1,280
18	28	640	52	81	1,600
20	31	960	56	88	
22	34	1,280	57	89	1,280
25	39	640	60	94	640
26	40	1,920	62	97	960
27	42	960	64	100	1,280
28	44		65	102	320
30	47	320	68	106	1,920
33	51	1,920	70	110	
35	55		72	113	320
40	62	1,920	76	119	960

SPLICES AND BOLTS FOR ONE MILE OF TRACK.

30 feet	of Rail	requires	740 Splices;	1,408	Bolts and	Nuts.
28	"	"	754 "	1,508	"	"
27	"	"	782 "	1,564	"	"
25	"	"	844 "	1,688	"	"
24	"	"	880 "	1,760	"	"

WEIGHT OF RAILROAD SPIKES.

Size in Inches.	No. per Keg of 150 lbs.	No. per lb.	Size in Inches.	No. per Keg of 150 lbs.	No. per lb.
4½ × 7/16	526	3·5	5½ × ½	350	2·33
4½ × ½	400	2·66	5½ × 9/16	289	1·93
5 × 3/8	705	4·7	5½ × 5/8	218	1·46
5 × 7/16	488	3·25	6 × ½	310	2·07
5 × ½	390	2·6	6 × 9/16	262	1·75
5 × 9/16	295	1·97	6 × 5/8	196	1·30
5 × 5/8	257	1·71			

WIRE.

Multiply by 1·02 for weight of steel; by 1·16 for copper; by 1·09 for brass.

No.	American Wire Gauge.		Birmingham Wire Gauge.	
	Diam. of Wire in Inches.	Weight of Iron Wire in lbs. per Lineal Foot.	Diam. of Wire in inches.	Weight of Iron Wire in lbs. per Lineal Foot.
0000	·46	·561	·454	·546
000	·4096	·445	·425	·479
00	·3648	·353	·380	·383
0	·3249	·280	·340	·306
1	·2893	·222	·300	·238
2	·2576	·176	·284	·214
3	·2294	·139	·259	·178
4	·2043	·111	·238	·150
5	·1819	·0877	·220	·128
6	·1620	·0696	·203	·109
7	·1443	·0552	·180	·0859
8	·1285	·0438	·165	·0721
9	·1144	·0347	·148	·0580
10	·1019	·0275	·134	·0476
11	·0907	·0218	·120	·0382
12	·0808	·0173	·109	·0315
13	·0720	·0137	·095	·0239
14	·0641	·0109	·083	·0183
15	·0571	·00863	·072	·0137
16	·0508	·00684	·065	·0112
17	·0452	·00543	·058	·00891
18	·0403	·00430	·049	·00636
19	·0359	·00341	·042	·00467
20	·0320	·00271	·035	·00325
21	·0285	·00215	·032	·00271
22	·0253	·00170	·028	·00208
23	·0226	·00135	·025	·00166
24	·0201	·00107	·022	·00128
25	·0179	·000849	·020	·00106
26	·0159	·000673	·018	·000859
27	·0142	·000534	·016	·000678
28	·0126	·000423	·014	·000519
29	·0113	·000336	·013	·000448
30	·0100	·000266	·012	·000382
31	·0089	·000211	·010	·000265
32	·0079	·000167	·009	·000215
33	·0071	·000133	·008	·000170
34	·0063	·000105	·007	·000130
35	·0056	·0000837	·005	·0000662
36	·0050	·0000662	·004	·0000444

TABLE OF THE WEIGHT OF CAST-STEEL, TWELVE INCHES IN LENGTH.

Square.						Round.					
Size. In.	Weight. Lbs.	Oz.	Size. In.	Weight. Lbs.	Oz.	Diam. In.	Weight. Lbs.	Oz.	Diam. In.	Weight. Lbs.	Oz.
0¼	0	3½	6½	143	10	0¼	0	2¾	6½	112	13
0⅜	0	7¾	6¾	154	14	0⅜	0	6	6¾	121	10
0½	0	13¾	7	166	9	0½	0	10½	7	130	13
0⅝	1	5¼	7¼	178	12	0⅝	1	0½	7¼	140	4
0¾	1	14¾	7½	191	4	0¾	1	8	7½	150	3
0⅞	2	10	7¾	204	4	0⅞	2	1	7¾	160	6
1	3	6½	8	217	12	1	2	11	8	170	14
1⅛	4	5½	8¼	231	7	1⅛	3	6	8¼	181	12
1¼	5	5	8½	245	10	1¼	4	7½	8½	192	15
1⅜	6	7	8¾	260	5	1⅜	5	1	8¾	204	7
1½	7	11	9	275	6	1½	6	0	9	216	4
1⅝	9	0	9¼	290	14	1⅝	7	1	9¼	228	7
1¾	10	2½	9½	306	13	1¾	8	3¼	9½	240	15
1⅞	12	0	9¾	322	14	1⅞	9	6½	9¾	253	13
2	13	10	10	340	0	2	10	11½	10	267	0
2⅛	15	5½	10¼	357	4	2⅛	12	6½	10¼	280	8
2¼	17	3½	10½	374	14	2¼	13	15	10½	294	6
2⅜	19	3	10¾	392	15	2⅜	15	8	10¾	308	8
2½	21	4	11	411	7	2½	17	3	11	323	1
2⅝	23	7	11¼	430	5	2⅝	18	15	11¼	337	15
2¾	25	11½	11½	449	11	2¾	20	12½	11½	353	2
2⅞	28	2	11¾	469	7	2⅞	22	12	11¾	368	10
3	30	10	12	489	8	3	24	12	12	384	8
3⅛	33	3½	12½	531	4	3⅛	26	13½	12½	417	3
3¼	35	15	13	574	10	3¼	28	4	13	451	4
3⅜	38	11½	13½	619	10	3⅜	30	2	13½	486	9
3½	41	10½	14	666	7	3½	32	14	14	523	5
3⅝	44	11	14½	714	14	3⅝	35	1	14½	561	6
3¾	48	0	15	765	0	3¾	37	10	15	600	12
3⅞	51	0	15½	816	14	3⅞	40	1½	15½	641	7
4	54	8	16	870	10	4	42	14	16	683	8
4⅛	57	13½	16½	925	10	4⅛	45	7	16½	726	14
4¼	61	6	17	982	10	4¼	48	4	17	771	10
4⅜	65	1	17½	1,041	4	4⅜	51	2	17½	817	11
4½	68	14	18	1,101	10	4½	54	1	18	865	1
4⅝	72	12	18½	1,163	10	4⅝	57	2	18½	913	13
4¾	76	12	19	1,227	7	4¾	60	4	19	963	14
4⅞	80	13	19½	1,292	14	4⅞	63	8	19½	1,015	4
5	85	0	20	1,360	0	5	66	12	20	1,068	0
5⅛	89	5	20½	1,429	4	5⅛	70	2	20½	1,122	1
5¼	93	12	21	1,499	7	5¼	73	10	21	1,177	7
5⅜	98	4	21½	1,571	10	5⅜	77	2	21½	1,234	4
5½	102	14	22	1,645	9	5½	80	12	22	1,292	4
5⅝	107	8	22½	1,721	4	5⅝	84	7	22½	1,351	12
5¾	112	8	23	1,798	10	5¾	88	4	23	1,412	7
5⅞	117	11	23½	1,877	10	5⅞	91	7	23½	1,474	12
6	122	7	24	1,958	6	6	96	2	24	1,538	0
6¼	132	13				6¼	104	4			

WEIGHTS AND SIZES OF CUT-NAILS—COMMON NAILS.

Name.	Length Inches.	Number of Nails per lb.	Name.	Length Inches.	Number of Nails per lb.
2 penny	1	716	10 penny	3	66
3 " fine.	1⅛	626	12 "	3¼	50
3 "	1¼	440	20 "	4	32
4 "	1½	300	30 "	4½	
5 "	1¾	210	40 "	5	
6 "	2	163	50 "	5½	
7 "	2¼	123	60 "	6	
8 "	2½	93			

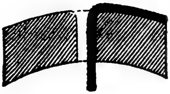
WIRE ROPES.

Wire ropes for colliery use are made of either iron or steel, and are generally round. Flat wire ropes are sometimes used, but the round rope is the favorite for many reasons, and is almost invariably used in American practice. Therefore we will confine this portion of our Pocket-Book to round wire ropes of iron or steel.

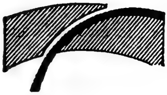
Taper-ropes are sometimes used, the idea being to produce a rope of uniform strength, that is, to have it less strong and of less diameter at the cage-end, where the load is least, and greater in strength and diameter at the drum-end, where the load is greatest. The theory is correct, and some weight of rope is saved, but practically there is not much advantage, and it is doubtful whether taper-ropes will ever be used as a general thing at collieries. The long-established conviction that the best of all ropes for colliery use is a round one made of steel or iron, has never been overcome, and it is safe to say never will be.

Steel ropes are in some respects superior to iron ropes, and are therefore gaining in favor every year. The principal advantage is that the rope has a greater strength with a less size, consequently there is less weight, and it can pass round pulleys and drums with less injury.

In fastening a rope to a drum there is often a grievous error made. Men that will not think of passing a rope round a pulley of too small diameter will insert it in the drum-rim in such a way as to make a very sharp curve, and make a weak point in the rope that would not otherwise exist. The following cuts show the right and the wrong way of passing the rope through the drum-rim.



The Wrong Way.



The Right Way.

The securing of the rope to the drum or the drum-shaft by several coils around each is unnecessary. With one coil around either the drum or the shaft, a pull of 1 lb. will resist a weight of 9 lbs.; if two coils, a pull of 1 lb. will resist 9×9, or 81; if three coils, $9 \times 9 \times 9$, or 729, and so on, multiplying the former result by 9 for each additional coil.

In laying out the position of the engine at a shaft, a distance of 30 yds. from the head-sheave to the drum will be found to answer best. No rope should be subjected to a load greater than the safe working-strain. There is, of course, in all cases a wide margin between the breaking-strain and the working-load, and on this account it is supposed that no risk is run by putting on a load considerably in excess of the maker's safe working-strain. This is a mistake, and it is false economy. A rope overloaded is unduly strained, and, although showing no defect at the moment, it will some day give way without warning. Drums and rope-pulleys should have as great diameters as the engines will allow. Ropes should be regularly and properly greased. This can best be done with brushes, but brush-greasing takes considerable time. While it pays in the long run, it is not always convenient to use brushes. A fairly good and cheap arrangement for greasing ropes is to make a wooden trough, wide at top, and small enough at bottom to fit loosely around the rope. Make a mixture of 1 barrel of coal-tar or pitch-tar to 1 bushel of fresh-slacked lime, and boil it well. Then fill the trough with this mixture and run the rope slowly through it.

A rope should not be changed from a large drum to a small one, for it will not work so well, neither will it last as long. This is also true, but in a lesser degree, of ropes changed from a small drum to a large one. After having been used for some time on a drum, the rope adapts itself to that diameter, and resents a change. Rope-sheaves should be made to fit the rope, and should be filled in with well-seasoned blocks of oak or other hard wood set on end. This will save the rope and increase adhesion.

To find the minimum diameter for a drum or sheave.—Let the circumference of the rope in inches equal the diameter of the drum or sheave in feet.

To find the maximum diameter for a drum or sheave.—The circumference of the rope in inches, multiplied by 2 = the maximum diameter of drum or sheave in feet.

Wire rope is made with either hemp or wire center. Hemp center is more pliable than wire and will wear better where there are short bends.

WEIGHT AND STRENGTH OF ROPES.

C = Circumference of rope in inches.
L = Working-load of rope in tons.
S = Breaking-strain of rope in tons.
W = Weight of rope in lbs. per foot.

$$C = \sqrt{\frac{L}{k}}; \qquad L = C^2 \times k;\ S = C^2 \times x;\ W = C^2\, y, \text{ or } W = L\, z.$$

Table of Values of k, x, y, and z.

Description of Rope.	k	x	y	z
Iron wire rope..................................	·290	1·80	·145	·483
Steel wire rope...............	·450	2·80	·148	·318
Common hemp................................	·032	·18	·03	1·00
Best hemp	·108	·65		
White Manilla	·045	·27	·0295	·656

EXAMPLES.

What is the circumference of a steel rope to stand a working-load of 6⅓ tons?

$$C = \sqrt{\frac{L}{k}} \text{ or Circumference } = \sqrt{\frac{6·33}{·450}} \text{ or } 3·75 \text{ in., or } 3\tfrac{3}{4} \text{ in.}$$

What is the working-load of an iron wire rope 2 ins. in circumference?

$L = C^2 \times k$ or Load $= 2^2 \times ·290 = 1·16$. tons.

What is the breaking-strain of the same rope?

$S = C^2 \times x$ or Strain $= 2^2 \times 1·80 = 7·20$ tons.

What is the weight per foot of a steel wire rope 3 in. in circumference?

$W = C^2 \times y$ or Weight $= 3^2 \times ·148 = 1·33 +$ lbs. or $W = L \times z$, or Weight = the working-load in tons multiplied by 0·318.

TABLE OF WORKING-STRENGTH OF ROPES IN TONS.

Circum. Inches.	Hemp.		Wire.		Circum. Inches.	Hemp.		Wire.	
	Common.	Good.	Iron.	Steel.		Common.	Good.	Iron.	Steel.
1	·032	·046	·29	·45	4¼	·578	·831	5·24	8·13
1¼	·050	·072	·45	·70	4½	·648	·932	5·87	9·11
1½	·072	·104	·65	1·01	4¾	·722	1·038	6·54	10·15
1¾	·098	·141	·89	1·38	5	·800	1·150	7·25	11·25
2	·128	·184	1·16	1·80	5½	·968	1·392	8·77	13·61
2¼	·162	·233	1·47	2·28	6	1·152	1·656	10·44	16·20
2½	·200	·288	1·81	2·81	6½	1·352	1·944	12·25	19·01
2¾	·242	·348	2·19	3·40	7	1·568	2·254	14·21	22·05
3	·288	·414	2·61	4·05	7½	1·800	2·588	16·31	25·31
3¼	·338	·486	3·06	4·75	8	2·048	2·944	18·56	28·80
3½	·392	·564	3·55	5·51	8½	2·312	3·324	20·95	32·51
3¾	·450	·647	4·08	6·33	9	2·592	3·726	23·49	36·45
4	·512	·736	4·64	7·20	10	3·200	4·600	29·00	45·00

The above table is calculated for wire ropes with wire center. If the rope has a hemp center, deduct 10% from the working-strength.

TABLE OF WEIGHT OF ROPES IN LBS. PER FOOT.

Circum. Inches.	Hemp.		Wire.		Circum. Inches.	Hemp.		Wire.	
	Common.	Good.	Iron.	Steel.		Common.	Good.	Iron.	Steel.
1	·03	·04	·145	.148	4¼	·541	·723	2·629	2·673
1¼	·0467	·0633	·231	·236	4½	·608	·810	2·936	2·997
1½	·0683	·09	·327	·333	4¾	·677	·903	3·271	3·39
1¾	·0916	·1233	·443	·455	5	·750	1·00	3·625	3·700
2	·12	·160	·580	·593	5½	·908	1·21	4·386	4·477
2¼	·152	·203	·733	·751	6	1·08	1·44	5·12	5·328
2½	·188	·250	·906	·9267	6½	1·268	1·69	6·126	6·253
2¾	·227	·303	1·096	1·121	7	1·470	1·96	7·105	7·252
3	·270	·360	1·305	1·335	7½	1·688	2·25	8·156	8·325
3¼	·317	·423	1·531	1·567	8	1·920	2·56	9·280	9·472
3½	·368	·490	1·776	1·816	8½	2·175	2·89	10·476	10·693
3¾	·421	·563	2·038	2·087	9	2·430	3·24	11·745	11·988
4	·480	·640	2·320	2·373	10	3·00	4·00	14·5	14·8

NOTE.—These weights are calculated for wire ropes with wire center. Ropes with hemp center weigh about 10% less.

WIRE-ROPE SPLICING AND FASTENING.

The splicing of wire ropes in a first-class manner, has always been a source of trouble to colliery officials. The following directions for doing this work are by Messrs. T. E. Hughes of Scranton, Pa., and J. B. Stone, of Worcester, Mass., who jointly spent several months in preparing the paper, so as to have it in plain and concise terms.

SPLICING.

The tools required will be a small marlin-spike, nipping cutters, and either clamps or a small hemp-rope sling with which to wrap around and untwist the rope. If a bench-vise is accessible, it will be found very convenient for holding the rope.

In splicing rope, a certain length is used up in making the splice. An allowance of not less than 16 feet for ½-inch rope, and proportionately longer for larger sizes, must be added to the length of your endless rope in ordering.

Having measured, carefully, the length the rope should be after splicing, and marked the points *M* and *M′*, *Fig.* 1, you unlay the strands from each end *E* and *E′* to *M* and *M′* and cut off the center at *M* and *M′*, and then :

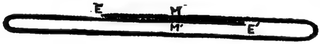


Fig. 1.

First. Interlock the six unlaid strands of each end alternately and draw them together so that the points *M* and *M′* meet as shown in *Fig.* 2.

Second. Unlay a strand from one end, and following the unlay closely, lay into the seam or groove it opens, the strand opposite it belonging to the other end of the rope, until within a length equal to three or four times the length of one lay of the rope, and cut the other strand to about the same length from the point of meeting, as shown at *A*, *Fig.* 3.

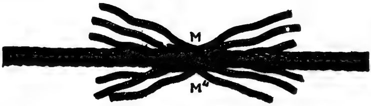


Fig. 2.

Third. Unlay the adjacent strand in the opposite direction, and following the unlay closely, lay in its place the corresponding opposite strand, cutting the ends as described before at *B*, *Fig.* 3.

You have now four strands laid in place terminating at *A* and *B*, with the eight remaining at *M M′*, as shown in *Fig.* 3.

It will be well after laying each pair of strands to tie them temporarily at the points *A* and *B*.

Pursue the same course with the remaining four pairs of opposite strands, stopping each pair about eight or ten turns of the rope short of the preceding pair, and cutting the ends as before.

Fig. 3.

You now have all the strands laid in their proper places with their respective ends passing each other, as shown in *Fig.* 4.

All methods of rope-splicing are identical to this point; their variety consists in the method of tucking the ends. The one given below is the one most generally practiced.

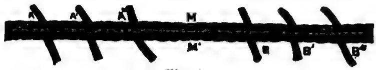


Fig. 4.

It now remains to secure the ends. Clamp the rope either in a vise at a point to the left of *A*, *Fig.* 4, and by a hand-clamp applied near *A*, open up the rope by untwisting sufficiently to cut the core at *A*, and seizing it with the nippers, let your assistant draw it out slowly, you following it closely, crowding the strand in its place until it is all laid in. Cut the core where the strand ends, and push the end back into its place. Remove the clamps and let the rope close together around it. Draw out the core in the opposite direction and lay the other strand in the center of the rope, in the same manner. Repeat the operation at the five remaining points, and hammer the rope lightly at the points where the ends pass each other at *A*, *A*, *B*, *B*, &c., with small wooden mallets, and the splice is complete, as shown in *Fig.* 5.

Fig. 5.

If a clamp and vise are not obtainable, two rope slings and short wooden levers may be used to untwist and open up the rope.

A rope spliced as above will be nearly as strong as the original rope, and smooth everywhere. After running a few days, the splice, if well made, cannot be pointed out except by the close examination of an expert.

WIRE-ROPE FASTENINGS.

Thimble spliced in, ordinary style, is shown in Fig. 6. In this method, the wires, after being frayed out at the end and the rope bent around the thimble, are laid snugly about the main portion of the rope and securely fastened by wrapping with stout wire; the extreme ends which project below this wrapping being folded back, as shown at *a*.

Fig. 6.

Another style of thimble-splicing is shown in Fig. 7. In this case the strands are interlocked as in splicing, and the joint is wrapped with wire as in the former method.


Fig. 7.

The socket-fastening is shown in Fig. 8. The hole in which the rope-end is fastened is conical in shape. The rope is generally secured by fraying out the wires at the end, the interstices being filled up with spikes driven in tightly. The whole is finally cemented by pouring in molten Babbit metal. This makes a much neater fastening than either of those shown in Figs. 6 and 7, but it does not possess anything like as much strength. But thimbles possess a serious disadvantage. The thimble is usually made of a piece of curved metal bent around into an oval shape as shown in Figs. 6 and 7, with the groove, in which the rope lies, outside; the ends coming together in a sharp point at *x*. When weight is placed on the rope, the strain on the thimble is apt to


Fig. 8.

cause one end to wedge itself beyond or past the other, and with its sharp edge it cuts the strands in the splice. Mr. William Hewitt, of Trenton, N. J., while testing the strength of wire ropes, recently, discovered this tendency, and experimented with sockets with the idea of devising some method of fastening the rope securely in the socket. He found that by adopting the following plan he secured good results:

The wires, after being frayed out at the end, were bent upon themselves in hook-fashion, the prongs of some being longer than others, so that the bunch would conform to the conical aperture of the socket, and the melted Babbit metal was finally run in as usual. The rope was subjected to a strain of over 129,000 lbs., and the wires in the socket were unaffected. The simplicity of this method commends itself to practical men.

CHAINS.

The links of iron chains are usually made as short as is consistent with easy play, so as to make them less liable to kink, and also to prevent bending when wound around drums, sheaves, etc.

The strength of chains varies, owing to the nature of the iron from which they are made, and their mechanical construction. The following table is approximately correct for ordinary iron chains.

TABLE OF WEIGHT AND STRENGTH OF CHAINS.

Diameter of Rod of which the Links are Made.	Weight of Chain per Running Foot.	Working-Strength.	Breaking-Strain.	Diameter of Rod of which the Links are Made.	Weight of Chain per Running Foot.	Working-Strength.	Breaking-Strain.
Ins.	Lbs.	Tons.	Tons.	Ins.	Lbs.	Tons.	Tons.
3/16	·325	·19	·773	1	9·26	5·71	22·00
1/4	·579	·36	1·37	1 1/8	11·7	7·23	26·44
5/16	·904	·45	2·14	1 1/4	14·5	9·00	32·64
3/8	1·30	·85	3·09	1 3/8	17·5	10·80	39·42
7/16	1·78	1·09	4·20	1 1/2	20·8	13·00	47·60
1/2	2·31	1·43	5·50	1 5/8	24·4	15·24	55·14
9/16	2·93	1·80	6·96	1 3/4	28·4	17·65	63·97
5/8	3·62	2·23	8·58	1 7/8	32·6	20·27	73·44
11/16	4·38	2·70	10·39	2	37·0	23·10	83·55
3/4	5·21	3·21	12·36				
13/16	6·11	3·80	14·42				
7/8	7·10	4·40	16·80				
15/16	8·14	5·00	19·32				

Chains of warranted superior iron will stand 25% more strain before breaking.

ELEMENTS OF MECHANICS.

In this department we propose to treat only of the elements of machinery. All machinery, however complicated, is merely a combination of the six elementary forms, viz.: the lever, the wheel and axle, the inclined plane, the wedge, and the pulley; and these six can be still further reduced to the lever and the inclined plane. They are termed powers, but they do not produce force; they are only methods of applying and directing it.

The law of all mechanics is:

The power multiplied by the distance through which it moves, is equal to the weight multiplied by the distance through which it moves.

Thus, 20 lbs. of power moving through 5 ft. = 100 lbs. of weight moving through 1 ft.

LEVERS.

There are three classes of levers. They are: I. Power at one end, weight at the other, and fulcrum between; II. Power at one end, fulcrum at the other, and weight between; III. Weight at one end, fulcrum at the other, and power between.

The handle of a blacksmith's bellows is a lever of the first class. The hand is the power and the bellows the weight, with the pivot between as the fulcrum. An oar is a lever of the second class. The hand is the power, the boat the weight, and the water the fulcrum. The treadle of a sewing-machine is a lever of the third class. The foot is the power, the hinge at the back of the foot is the fulcrum, and the moving of the machinery is the weight.

The lever is in equilibrium when the arms balance each other. The distance through which the power and the weight move depends upon the comparative length of the arms. Let P*d* represent power's distance from the fulcrum (F,) and W*d* weight's distance; then if P*d* is twice W*d*, the power will move twice as far as the weight. Substituting these terms in the law of mechanics, we have

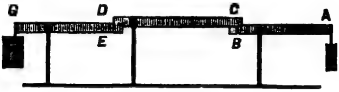
$$P \times Pd = W \times Wd, \text{ or } Pd : Wd :: W : P.$$

In first and second-class levers as ordinarily used, we gain power and lose time; in the third-class we lose power and gain time.

Practical Example.—Having a weight of 2,000 lbs. to lift with a lever, the short end of which is 2 ft. from the fulcrum and the long end 10 ft., how much power will be required?

$$Pd : Wd :: W : P, \text{ or } 10 : 2 :: 2{,}000 : 400 \text{ lbs.}$$

The compound lever consists of several levers so constructed that the short arm of the first acts on the long arm of the second, and so on to the last.



Compound Lever.

If the distance from A to the fulcrum be four times the distance from the fulcrum to B, then a power of 5 lbs. at A will lift 20 lbs. at B. If the arms of the second lever are of the same comparative length, the 20 lbs. power obtained at B will exert a pressure of 80 lbs. on E; and, if the third lever has the same comparative lengths, this 80 lbs. at E will lift 320 lbs at G. Thus a power of 5 lbs. at A will balance a weight of 320 lbs. at G. But, in order to raise the weight one foot, the power must pass through $\frac{320}{5}$, or 64 feet.

The wheel and axle is a modification of the lever. The ordinary windlass is a common form. The power is applied to the handle, the bucket is the weight, and the axis of the windlass is the fulcrum. The long arm of the handle is the lever, and the short arm is the semi-diameter of the axle. Thus, O is the fulcrum, O A the long arm, and O B the short arm. The wheel and axle has the advantage that it is a kind of perpetual lever. We are not obliged to prop up the weight and readjust the lever, but both arms work continuously.

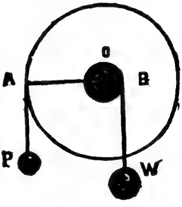


Fig. 2.

By turning the handle or wheel around once, the rope will be wound once around the axle, and the weight will be lifted that distance. Applying the law of mechanics, we have power × the circumference of the wheel = the weight × circumference of the axle; or, as the circumference of circles are proportional to their radii, we have

$$P : W :: \text{radius of the axle} : \text{radius of the wheel.}$$

Wheelwork consists of a series of wheels and axles which act upon each other on the principle of a compound lever. The cogs on the circumference of the wheel are termed *teeth*, on the axle *leaves*, and the axle itself *a pinion*. If the radius of the wheel F is 12 inches, and that of the pinion 2 inches, then a power of 1 lb. will apply a force of 6 lbs. to the second wheel E. If the radius of this is also 12 inches, then the second wheel will apply a force of 36 lbs. to the third wheel. This, acting on its axle, will balance a W of 216 lbs. In order, however, to lift this amount, according to the principle already named, the weight will only pass through $\frac{1}{216}$ of the distance of the power. Thus, power is gained and speed lost. To reverse this we apply power to the axle, and, with a correspondingly heavy power, gain speed.

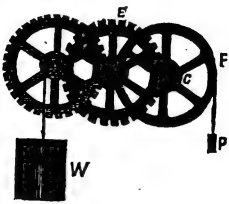


Fig. 3.

The inclined plane.—The principle of the inclined plane is that we gain power and lose time. With an inclined plane a certain load can be raised to any perpendicular height with less power than it can be lifted vertically. In the annexed cut we see that the power must descend a distance equal to A C in order to elevate the weight to the height B C. Applying the law of mechanics, we have P × length of the inclined plane = W × the height of the inclined plane, or P : W :: height of inclined plane : length of inclined plane, or P = W × the sine of angle of inclination.

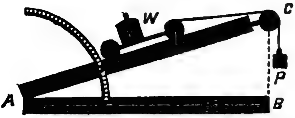


Fig. 4.

To find the weight required to balance any weight on any inclined plane.—Multiply the given weight by the sine of the angle of inclination.

Thus, to find the weight required to balance a loaded car weighing 2,000 lbs. on a plane pitching 18°, we multiply 2,000 by the sine of 18°, or 2,000 × ·3090170 = 618·034 lbs.

Or, if the length of the plane and the vertical height is given, multiply the load by the quotient of the vertical height divided by the length.

Thus, if your plane is 300 ft. long and rises 92·7 ft., and the load is 2,000 lbs,, the formula is as follows:—$2{,}000 \times \frac{92 \cdot 7}{300} = 618+$.

These rules are theoretically correct, but in practice, allowance must be made for friction.

To find the horse-power required to hoist the same load up the same plane in a given time, say one minute, the rule is.—Add to the weight of the load, the weight of the rope, divide the sum by 33,000 (or the number of pounds 1 horse-power will raise 1 ft. high in 1 minute), and multiply the quotient by the vertical height to be overcome.

Thus, assuming that the rope will weigh 500 lbs., the load at starting becomes 2,500 lbs. Then $\frac{2{,}500}{33{,}000} \times 92 \cdot 7 = 7+$ horse-power.

To this should be added about 30% for contingencies, friction, etc.

The screw consists of an inclined plane wound around a cylinder. The inclined plane forms the thread, and the cylinder the body. It works in a nut which is fitted with reverse threads to move on the thread of the screw. The nut may run on the screw, or the screw in the nut. The power may be applied to either as desired by means of a wrench or a lever.

When the power is applied at the end of a lever, it describes a circle of which the lever is the radius. The distance through which the power passes, is the circumference of the circle; and the height to which the weight is lifted at each revolution of the screw, is the distance between two of the threads. Applying the law of mechanics, we have P × circumference of circle = W × intervals between the threads, or

P : W :: interval : circumference.

The power of the screw may be increased by lengthening the lever or by diminishing the distance between the threads.

The wedge usually consists of two inclined planes placed back to back. In theory the same formula applies to the wedge as to the inclined plane, viz.

P : W :: thickness of wedge : length of wedge.

In practice, however, this by no means accounts for its prodigious power. Friction, in the other mechanical powers, materially diminishes their efficiency; in this it is essential, since, without it, after each blow the wedge would fly back and the whole effect be lost. Again, in the others, the power is applied as a steady force; in this it is a sudden blow and is equal to the momentum of the hammer.

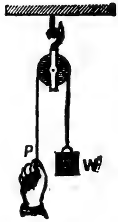


Fig. 5.

The pulley is simply another form of the lever which turns about a fixed axis or fulcrum. It consists of a wheel, within the grooved edge of which runs a cord. Force may be transmitted from one point to another either by pushing with a rigid bar, or by pulling with a flexible cord. The advantage of the latter method is that the direction of the force may be changed. This is accomplished by a single fixed pulley, as shown in Fig. 5. Here there can be no gain of power or speed, as the hand P must pull down as much as

the weight W, and both move with the same velocity. It is simply a lever of the first class with equal arms.

Movable pulley.—A form of the single pulley, where it moves with the weight, is shown in Fig. 6. In this one-half of the barrel is sustained by the hook, while the hand lifts the other. Since the power is only one-half the weight, it must move through twice the space; in other words, by taking twice the time, we can lift twice as much. Here power is gained and time lost.

Fig. 6.

Combination of pulleys.—(1) In Fig. 7 we have the W sustained by three cords, each of which is stretched by a tension equal to the P, hence 1 lb. of power will balance 3 lbs. of weight. (2) In Fig. 8, the power will in the same manner sustain a W of 4 lbs., and must descend 4 inches to raise the W one inch. (3) In the cord marked 1, 1 (Fig. 9), each part has a tension equal to P; and in the cord marked 2, 2, each part has a tension equal to 2 P, and so on with the other cords. The sum of the tensions acting on W is 16, hence W = 16 P.

Fig. 7.

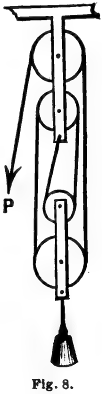


Fig. 8.

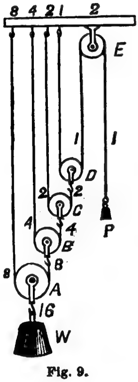


Fig. 9.

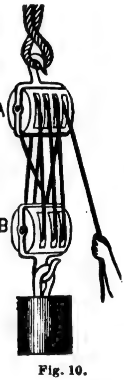


Fig. 10.

Fig. 10 represents the ordinary "tackle block" used by mechanics.

In all combinations of pulleys, nearly one-half the effective force is lost by friction. In most of the forms in use, the W is equal to the P multiplied by twice the number of movable pulleys.

NOTE.—In the foregoing formulæ, etc., friction is not considered, the idea being to give readers an elementary knowledge of the principles of the elements of mechanics.

FRICTION.

Friction is the resistance caused by the surface over which a body moves. It is of two kinds, *sliding* and *rolling*. If the surface of a body could be made perfectly smooth there would be no friction; but, in spite of the most exact polish, the microscope reveals minute projections and cavities. We fill these with oil or grease, and thus diminish friction. Friction, between different bodies, varies curiously.

Since no surface can be made perfectly smooth, some separation of the two bodies must, in all cases, take place in order to clear such projections as exist

on the surfaces. Therefore friction is always more or less affected by the amount of the perpendicular pressure which tends to keep them together.

The ultimate friction is the greatest frictional resistance that a body sliding over the other is capable of opposing to any sliding force when at rest.

The proportion which the ultimate friction in a given case bears to the perpendicular pressure is called the *coefficient of friction*. The coefficient of friction is usually expressed in decimals; but sometimes, as in the case of cars and engines, it is expressed in pounds (of friction) per ton.

The coefficient of friction equals the ultimate friction divided by the perpendicular pressure, and the ultimate friction equals the perpendicular pressure multiplied by the coefficient of friction.

Thus, if we have a block weighing 100 lbs. standing on another block, and it takes 35 lbs. pressure to slide it, then the coefficient of friction = $\frac{35}{100}$, or ·35.

TABLE OF COEFFICIENTS OF FRICTION OF SMOOTH, CLEAN, AND DRY PLANE SURFACES.

Materials.	Coefficients of Friction.
Oak on oak	·40
Wrought-iron on oak	·62
Wrought-iron on cast-iron	·19
Wrought-iron on wrought-iron	·14
Wrought-iron on brass	·17
Cast-iron on cast-iron	·15
Cast-iron on brass	·15
Steel on cast-iron	·20
Steel on steel	·14
Steel on brass	·15
Brass on cast-iron	·22
Brass on wrought-iron	·16
Brass on brass	·20

The above coefficients are only approximate, for the coefficient will vary with the intensity of the pressure and the velocity; and also with the conditions of the atmosphere. But they are correct enough for practical purposes.

The friction of liquids moving in contact with solid bodies is independent of the pressure because the forcing of the particles of the fluid over the projections on the surface of the solid body is aided by the pressure of the surrounding particles of the liquid which tend to occupy the places of these forced over. Therefore the coefficients of friction of liquids over solids do not correspond with those of solids over solids. The resistance is directly as the area of surface or contact.

TABLE OF COEFFICIENTS OF FRICTION OF SMOOTH PLANE SURFACES, PERFECTLY LUBRICATED WITH TALLOW.

Substances.	Coefficient of Friction.
Oak on oak	·079
Oak on cast-iron	·080
Oak on wrought-iron	·098
Wrought-iron on oak	·085
Wrought-iron on cast-iron	·103
Wrought-iron on wrought-iron	·082
Wrought-iron on brass	·103
Cast-iron on oak	·078
Cast-iron on cast-iron	·100
Cast-iron on brass	·103
Brass on cast-iron	·086
Brass on wrought-iron	·081
Steel on cast-iron	·105
Steel on wrought-iron	·093
Steel on brass	·056

COEFFICIENTS OF FRICTION IN AXLES.

Axle.	Bearing.	Ordinary Lubrication.	Lubricated Continuously.
Bell-metal	Bell-metal	·097	.....
Cast-iron	Bell-metal	·07	·049
Wrought-iron	Bell-metal	·07	·05
Wrought-iron	Cast-iron	·07	·05
Cast-iron	Cast-iron	·07	·05
Cast-iron	Lignumvitæ	·10	...
Wrought-iron	Lignumvitæ	·12	...

Friction naturally varies with the character of the surfaces, lubrication, and the nature of the lubricant. The best lubricants for the purposes should always be used, and the supply should be regular. When machinery is well lubricated, the lubricant keeps the surfaces apart, and the frictional resistance becomes very small, or about the same as the friction of liquids.

FRICTIONAL RESISTANCE OF SHAFTING.

Let K = Coefficient of friction.
Let W = Work absorbed in foot-lbs.
Let P = Weight of shafting and pulleys + the resultant stress of belts.
Let H = Horse-power absorbed.
Let D = Diameter of journal in inches.
Let R = Number of revolutions per minute.

Then:

ORDINARY OILING.	CONTINUOUS OILING.
$W = \cdot 0182 \times P \times D$;	$\cdot 0112 \times P \times D$.
$H = \cdot 000000556 \times P \times D \times R$;	$\cdot 000000339 \times P \times D \times R$.
$K = \cdot 066$;	$\cdot 044$.

As a rough approximation, 100 feet of shafting, 3 inches diameter, making 120 revolutions per minute, requires 1 horse-power.

COLLIERY MANAGEMENT.

PROSPECTING.

The prospector should have a good general knowledge of the coal-bearing strata, and should be a very observant man. He should know the nature of the rocks of the carboniferous era, and should know, from the nature of the ledges exposed, whether to expect to find coal or not, without much other searching.

The coal was formed during what is geologically known as the carboniferous period, and is therefore only found interstratified with the rocks of that age. These rocks are sandstones, shales, conglomerates, and occasionally limestones; and they are so similar to the rocks of the Devonian and Silurian ages (both older formations) that they cannot be distinguished except by the fossils. For a description of these fossils, the reader, not familiar with them, must consult some elementary geology; for such a description of them as would be necessary to familiarize him with their various forms and appearances would take up too much space in a volume such as this.

Therefore, assuming that the reader has either a practical acquaintance of coal geology or has a theoretical knowledge of it, we will pass on to the practical work of prospecting. When the presence of coal is suspected in a tract of land, a thorough examination of the surface and a study of the exposed rocks, in place, may result in the immediate discovery of coal, or in positive proof of its absence; or it may result in still further increasing the doubt or the belief that it does exist. The first procedure in prospecting a tract of land is to thoroughly traverse it, and note carefully any traces of smut, and all outcrops of every description, and whenever possible take the dip, and the course of the crop, with a pocket-compass. These outcrops are frequently more readily found along roads or streams than any place else on the tract. In traveling along the streams the prospector should pay particular attention to its bed and banks to see whether there are any small particles of coal in the bed of the stream, or any smut exposed along the washed banks. If small

pieces of coal are found in the stream a search up it and its tributaries will show where the crop from which the find came, is located. When the ravines and valleys are so filled with wash that no exposures are visible, and nothing is gained by a careful examination of them, the prospector must rely on topographical features to guide him. In this connection the following from *Report A C, Pennsylvania Geological Survey*, by H. M. Chance, is perhaps as complete a guide as has been written: "The topographical features which denote the presence of a bituminous coal-seam are easily recognized by any one familiar with the peculiarities of coal-measure topography. The most prominent of these is the bench or terrace which almost invariably occurs at the outcrop. The soft coal-seams, encased in harder rocks, are easily and rapidly eroded, and produce, by their rapid disintegration, a series of benches following their lines of outcrop. But, as every hard stratum will also produce a terrace of some kind, it is necessary to have some means of distinguishing a coal-terrace from a bench marking the outcrop of some other stratum. In the bituminous coal-regions, where the seams lie in the hills, with very slight, almost imperceptible dips, the site of a coal-bed is nearly always indicated by springs loaded with iron, which is deposited in ochery films upon the stones and vegetable matter over which the water flows. In the Anthracite regions the beds, being highly inclined, rarely furnish such an indication of their presence, except in the sharply-cut gaps and ravines eroded across the hills in which the coal occurs.

"The anthracite coal-terrace is often a well-marked topographical feature, but in many localities the site of the outcrop is not marked by any distinct bench or terrace, and surface examinations fail to disclose any important features. In tracing a coal-terrace the breadth is always affected by—

1. The thickness of the seam.
2. The dip of the bed.
3. The slope of the ground.

"When the bed dips *into* the hill, the terrace is broader than when the pitch is in an opposite direction, and when the surface slope is gentle, the terrace is generally broader than where a steep contour prevails.

"A good conception of the direction and strength of dip may be obtained by tracing a terrace for some distance and carefully noting its deflections from a straight line, and the relations of these to the contour of the ground. If the variation occasioned by a depression is toward the foot of the hill, the coal dips in the same direction with the slope of the ground, but if it runs in towards the top of the hill the reverse is true."

The terrace, or bench, having been determined, the next procedure is to discover on it some trace of coal. This trace may be found in the soil adhering to the roots of an overturned tree, or in the earth turned up at some animal's burrow.

When the presence of coal is thus detected, or if the indications otherwise are favorable, trial-trenches or shafts may be commenced. These trenches or shafts should be started a little below the supposed location of the crop, and should be driven towards the pitch at a depth of from five to ten feet. If no trace of coal is found in the first trench or shaft, it is not evidence of no coal, for the wash at this point may be too deep, or the trench may be too far down the hill. The next trial should be made some distance along the terrace, from the first, and the same rule be followed till the prospector is either satisfied by a number of trenches or shaftings, that there is no coal there, or until he strikes small fragments of coal or a well-defined smut. When this is found the trench must be extended up hill until it is traced to the bed from which it comes. In flat seams it is advisable to start a shaft a few feet above where the outcrop is supposed to be, and sink through the seam to the bottom.

It is seldom that such experiments fail in determining whether there is coal in the tract, for if careful examinations are made unmistakable evidences of its presence will be found.

As the crop is frequently wider than the seam, to determine its true thickness the shaft or trench, or a heading from it, should be continued in the solid coal till the top and bottom of the vein are both exposed and shown to be parallel with each other, when the true thickness may be measured. When the seam has a heavy dip, and crops on the side of a steep hill, a trial tunnel will be found superior to shafting.

These general principles will also be found useful in prospecting for any stratified mineral deposits, if slightly modified to suit the circumstances encountered, and they can, in many instances, be applied to the exploration of metalliferous deposits occurring in veins or fissures in metamorphic or igneous rocks.

PROSPECTING BY BORE-HOLES.

For the more extensive investigation of the coal-deposit in a tract, prospecting with either the diamond or jumper drill is resorted to. The Diamond drill is preferred in most instances, for with it, a core is obtained that shows the nature of the material passed through, and also gives a general idea of the dip of the measures. The jumper drill is only the system of hammer and jumper drilling, elaborated and worked by steam-power. It is done by the drill-rigs, same as used in the oil-regions for drilling oil-wells, and which are so familiar now, that a description of them is unnecessary. These drills do not furnish a core, but the experienced driller can tell from the action of his drill when he is passing from one stratum to another, and the sand-pump soon furnishes the sediment that determines its character; but it is impossible to secure as good results with this method as with the Diamond drill. The jumper or churn drill has, however, other uses in the development and working of coal, wherein it is both superior and cheaper than the Diamond drill. Diamond drills are built for both steam and hand-power, and where the hole is to be less than 300 ft. in depth, the hand-drill will be found cheaper, though slower in operation than the steam-drill.

Those who are prospecting for coal often have difficulty in determining the character or class of the coal found; and the following may prove of some service to those engaged in such work.

CLASSIFICATION OF COALS.

Coals may be broadly divided into two classes: Anthracite or Hard Coal, and Bituminous or Soft Coal.

Anthracite or Hard Coal.—Specific gravity, 1·30–1·70. This is the densest, hardest, and most lustrous of all varieties. It burns with little flame and no smoke, but gives a great heat. Contains very little volatile combustible matter. Color, deep black, shining; sometimes iridescent. Fracture, conchoidal.

Semi-Anthracite Coal is not so dense nor so hard as the true Anthracite. Its percentage of volatile combustible matter is somewhat greater, and it ignites more readily.

Bituminous or Soft Coals.—Specific gravity, 1·25–1·40. They are generally brittle; have a bright pitchy or greasy lustre and are rather fragile as compared with Anthracite. They burn with a yellow smoky flame and give on distillation hydrocarbon oils or tar.

Under the term Bituminous are included a number of varieties of coal which differ materially under the action of heat, giving rise to the general classification: Coking or caking coals, and free-burning coals.

Coking Coals are those which become pasty or semi-viscid in the fire; and when heated in a close vessel become partially fused and agglomerate into a mass of coherent coke. This property of coking may, however, become greatly impaired, if indeed not entirely destroyed, by weathering.

Free-Burning Coals have the same general characteristics as the coking-coals, but they burn freely without softening, and they do not fuse or cake together in any sensible degree.

Splint Coal has a dull black color and is much harder and less frangible than the coking-coal. It is readily fissile like slate; but breaks with difficulty on cross fracture. Ignites less readily, but makes a hot fire—constituting a good house coal.

Cannel Coal differs from the ordinary Bituminous coal in its texture. It is compact, with little or no lustre, and without any appearance of a banded structure. It breaks with a smooth conchoidal fracture; kindles readily, and burns with a dense smoky flame. It is rich in volatile matter and makes an excellent gas-coal. Color dull black and greyish-black.

Lignite or Brown Coal often has a lamellar or woody structure; is sometimes pitch-black, but more often rather dull and brownish-black. It kindles readily and burns rather freely with a yellow flame and comparatively little smoke; but it gives only a moderate heat. It is generally non-coking. The percentage of moisture present is invariably high—from 10 to 30%.

Semi-Bituminous Coal has the same general characteristics as the Bituminous, although it is usually not so hard and its fracture is more cuboidal. The percentage of volatile combustible matter is less. It kindles readily, and burns quickly with a steady fire; and is much valued as a steam-coal.

The sub-divisions given above are entirely arbitrary, as the different varieties of coal are found to shade insensibly into each other. The following, however, may be considered as a convenient classification:

Anthracite, with volatile combustible matter	2·5 to 6 %.
Semi-Anthracite, with volatile combustible matter	7 to 10 %.
Semi-Bituminous, with volatile combustible matter...........	12 to 20 %.
Bituminous, with volatile combustible matter	over 20 %.

THE COMPOSITION OF COALS.

A proximate analysis determines the proportion of those products of a coal having the most important bearing upon its uses. These substances as usually presented are:

Moisture, or water.
Volatile combustible matter.
Fixed carbon.
Sulphur.
Ash.

In addition to these, the following physical properties are generally given:

Color of ash.
Specific gravity.
Strength or hardness.

The determination of these eight factors gives a fair general idea of the adaptabilities of a coal.

Moisture, or water in coal, has no fuel-value, is an inert constituent, dug, handled, and hauled and finally expelled at a cost of fuel. Every per cent. of moisture means 20 lbs. less fuel for each ton of coal.

Volatile Combustible Matter is an important constituent of coal, the amount and quality deciding whether a coal is suitable for the manufacture of illuminating-gas. The coking of coal also is largely dependent upon this constituent. When a large percentage of volatile combustible matter is present, coals ignite easily and burn with a long yellow flame, and in ordinary combustion give out dense smoke, and form soot. This quality makes a fuel objectionable for railway and sometimes for naval use.

The Fixed Carbon is the principal combustible constituent in coal, and in bituminous and semi-bituminous coals the steaming value is in proportion to the percentage of fixed carbon. Though the fixed carbon of a coal evaporates much less water than an equivalent weight of the volatile combustible matter when properly burnt, in practice, so much of the latter is lost through careless firing, or improper furnace construction, that the relative steaming value of a coal may be fairly approximated by assuming the carbon to be the only useful constituent.

Sulphur will burn and develop heat, and is not inert like moisture and ash. But it corrodes grates and boilers, in the blast-furnace injures iron, and produces a hot short pig, and is objectionable in coal for forge use. In gas-making the sulphur must be removed. It usually occurs in coal in the form of iron pyrites, which oxidizing causes disintegration, and sometimes spontaneous combustion. It is then an element of danger and loss.

Ash is an inert constituent, which means 20 lbs. of weight to be handled and 20 lbs. loss per ton of coal, for each per cent. present. Water in coal is removed at the cost of fuel, while ashes are removed at extra cost of labor. It is estimated that if the cost of stoking coal is 6⅔ per cent. of the cost of coal (coal at $3.00 per ton, and labor at $1.00 per day), and with cost of handling ashes double that of stoking coal, 5 per cent. of ash will lessen the fuel-value of coal over 6 per cent.; 10 per cent. ash, over 12 per cent., and so on.

The Color of the Ash furnishes a rough estimate of the amount of iron contained in a fuel. Iron in an ash makes it more fusible, and increases its tendency to clinker. In domestic consumption where the temperature is low, the quantity of ash is of more importance than its fusibility, but, for steam purposes, where an excessive heat is required, ashes of a clinkering coal will fuse into a vitreous mass and accumulate upon the grate-bars and exclude the passage of necessary air. The practicability of employing a coal will often be determined by the quality of the clinkering of the ashes. Under such conditions such coals are best the ashes of which are nearly pure white and which contain little or no alkali nor any lime, and do not contain silica and alumina.

The Specific Gravity is an important factor when there is restriction of space, as on railway cars and in ship-bunkers. A given bulk of anthracite coal will weigh from 10 to 15 per cent. more than the same bulk of bituminous coal, so that from 10 to 15 per cent. more pounds of fuel can be carried in the same place.

The average specific gravity of anthracite coal is 1·5, and a cubic yard weighs about 2,531 lbs.

The average specific gravity of American bituminous coals, and of grades intermediate between them and anthracite, is about 1.325, and one cubic yard weighs about 2,236 lbs.

Strength or Hardness is valuable in preventing waste. In soft coal much is ground to dust in mining and at the tipple. In railway transportation soft

coal is crushed, which further increases the loss, and the coal reaches market in bad condition. A very soft coal is shipped in lump, and is not in so wide demand. For marine use a soft coal is objectionable, because of disintegration by the motion of the ship. Strength is a requisite for the use of raw coal in the blast-furnace, and also to prevent excessive loss of coal through the grates in ordinary furnaces.

STEAMING-COALS.

For steam-making the superiority of coals high in combustible constituents is admitted, and those with the higher percentage of fixed carbon are the most desirable. But the consideration of the steaming qualities of a coal involves also a consideration of the form of furnace and of all the conditions of combustion. The evaporative power of a coal in practice cannot be stated without reference to the conditions of combustion, and every practical test of a coal, to be thorough, should lead to a determination of the best form of furnace for that coal, and should furnish knowledge as to what class of furnaces in actual use such coal is specially adapted. It is not sufficient that in comparative tests of coals the same conditions should exist with each, but there should also be determined the best conditions for each coal.

Of coals high in fixed carbon, the semi-anthracites and the semi-bituminous rank as high as the anthracites in meeting the various requirements of a quick and efficient steaming-coal.

For railway use these coals have been found to excel anthracites in evaporating-power. The comparative absence in semi-bituminous coals, of smoke, which means loss of combustible matter as well as discomfort to the traveler, is sufficient to suggest the superiority of these coals over bituminous coals for such use. In fact, the high rate of combustion and the strong draught necessary in locomotives is particularly unfavorable to the economic combustion of bituminous coal. Such semi-bituminous coals are also specially well suited for small tubular boilers, fire-box steam boilers, or other forms with small unlined combustion-chambers in which the gases from bituminous coals become cooled, are not burnt, and deposit soot in the tubes.

Steaming-coal should kindle readily and burn quickly but steadily, and should contain only enough volatile matter to ensure rapid combustion. It should be low in ash and sulphur and should not clinker.

COALS FOR IRON-MAKING.

For the manufacture of iron and for metallurgical purposes coal is chiefly used after being converted into coke, though it is also used to a limited extent in the raw state. Coal directly used must be strong and not swell nor disintegrate so as to choke the furnace. It should be capable of producing a high heat and should not contain a large amount of sulphur or phosphorus.

COKE.

Coke is the fixed carbon of a coal, a fused and porous product produced by the distillation of the gaseous constituent. For metallurgical use it should be firm, tough, and bright, with a sonorous ring, and should contain not over 1% of sulphur. For blast-furnace use a dense coke is objectionable, and the best is the one with the largest cell-structure and the hardest cell-wall. A high percentage of volatile hydrocarbon is, as a rule, necessary for a good coking-coal.

The fusibility of the carbon, the amount of disposable hydrogen, the tenacity with which the gaseous constituents are held, all affect the results in coking. Further, coal which is mined near the outcrop and has been subjected to the influence of the weather, loses its capacity for coking. The process of manufacture should, however, be adapted to the character of the coal, as it has an important, though secondary influence upon the physical character, uniformity of quality and dryness of a coke. Coals of inferior grade are made to produce good coke in Europe by using coke-ovens in which the heat of the gases is applied externally to the coke-chamber, but the coal is generally first carefully crushed and washed. Further, the depth of the charge and length of heating have an important bearing.

As at present understood, and in the present mode of manufacture, the essential qualities of a good coking coal are that it shall contain not less than twenty nor more than thirty per cent. of volatile hydrocarbons and not too much ash; that on being heated it must pass through a thoroughly fused or pasty condition; and that when in this condition it must part with its volatile matter in such a manner as to form innumerable small pores.

If a coal contains less than twenty per cent. of volatile matter it will not fuse properly, whilst if it has more than thirty per cent. the porous structure will be unduly developed at the expense of the strength of the pore walls; on the other hand, many coals lying between these limits will not fuse at all, and therefore do not coke, while others fuse properly but give off their gas so as to form large and thin-walled pores.

DOMESTIC COALS.

In domestic use coal is burned in open grates, in closed stoves with ordinary fire-bowls and flat grates, or with basket-grates in small furnaces for hot-air heating and in cooking-stoves. In all these the coal that sustains a mild steady combustion, and remains ignited at a low temperature with a comparatively feeble draught, is the best. A coal burning with a smoky flame is objectionable as producing much soot and dirt, especially for open grates or cooking purposes. For self-feeding stoves or for base-burners a dry non-coking coal is necessary. A very free and fiercely burning coal is not desirable, particularly in stoves, as the temperature cannot be easily regulated. A sulphurous coal is also bad, as it produces stifling gases with a defective draught, and corrodes the grates and fire-bowls. The difficulty from clinkering is not so great in domestic uses, as the temperature is not generally high enough to fuse the ash. A stony, hard ash, which will not pass between the grate-bars, is bad, and light pulverulent ash is best.

The sizes of anthracite coal vary. The sizes of screen-mesh and bar-openings used for separating, range as follows:

Lump; over bars placed 7 to 9 inches apart.

Steamboat; over bars placed $3\frac{1}{2}$ to 5 inches apart and through bars 7 inches apart.

Broken	over a mesh $2\frac{3}{8}''$ to $2\frac{7}{8}''$,	through a mesh or bars $3\frac{1}{4}''$ to $4\frac{1}{2}''$.
Egg	over a mesh $1\frac{3}{4}''$ to $2\frac{1}{4}''$,	through a mesh or bars $2\frac{3}{8}''$ to $2\frac{7}{8}''$.
Large stove	over a mesh $1\frac{1}{4}''$ to $1\frac{7}{8}''$,	through a mesh or bars $1\frac{3}{4}''$ to $2\frac{1}{4}''$.
Small stove	over a mesh $1''$ to $1\frac{1}{4}''$,	through a mesh or bars $1\frac{1}{4}''$ to $1\frac{7}{8}''$.
Chestnut	over a mesh $\frac{5}{8}''$ to $\frac{3}{4}''$,	through a mesh or bars $1''$ to $1\frac{1}{4}''$.
Pea	over a mesh $\frac{3}{8}''$ to $\frac{5}{8}''$,	through a mesh or bars $\frac{5}{8}''$ to $\frac{3}{4}''$.
Buckwheat	over a mesh $\frac{3}{16}''$ to $\frac{3}{8}''$,	through a mesh or bars $\frac{3}{8}''$ to $\frac{5}{8}''$.
Dirt	over a mesh	through a mesh or bars $\frac{3}{16}''$ to $\frac{3}{8}''$.

The sizes of bituminous coal are lump, nut, and slack.

All coal that passes over bars $1\frac{1}{2}$ inches apart is called lump.

All coal that passes through bars $1\frac{1}{2}$ inches apart and over bars $\frac{3}{4}$ of an inch apart is called nut.

All coal that passes through bars $\frac{3}{4}$ of an inch apart is called slack.

GAS-COALS.

Coals suitable for the production of illuminating-gas should contain, at least, between 30 and 40% of volatile hydrocarbons.

ANALYSIS OF COALS.

To the practised eye, the appearance of a piece of coal will very frequently afford a good indication as to its character; but its real value can best be determined by means of a chemical analysis; and for general practical purposes what is known as a "proximate analysis" is usually considered sufficient.

By this we determine the percentages of moisture, volatile combustible matter, fixed carbon, sulphur, and ash. The method is as follows:

Water or Moisture.—Dry 5 to 10 grammes of the powdered coal in a counterpoised watch-glass in a water-bath at 212° F. until the weight is constant. From one to two hours is generally sufficient for this purpose. Note the loss in weight as moisture.

Volatile Matter.—One gramme of the powdered coal is heated in a platinum crucible, fitted closely with a lid, first at a red dull heat and until the flame of the escaping gases is no longer visible, and then at a full red heat for about five minutes. The crucible and its contents are allowed to cool thoroughly and then weighed. The loss in weight shows the percentage of volatile combustible matter and water. Deduct the water found in the previous experiment and note the difference as volatile combustible matter.

Ash.—The residue in the crucible consists of the fixed carbon, part of the sulphur, and the whole of the ash. To determine the latter, heat the crucible over a Bunsen burner or in a muffle until all the combustible matter has been burned off. Note the residue as ash.

Sulphur.—Fuse one gramme of the finely-pulverized coal with a mixture of ten grammes of carbonate of soda and six or seven grammes of nitrate of potash. Heat gently at first and until fusion is calm, then continue heating for about a quarter of an hour. Dissolve the contents of the crucible in water, acidulate with hydrochloric acid and evaporate to dryness to render silica insoluble. Re-dissolve in dilute acid—filter off the silica and precipitate the sulphur in the filtrate by means of chloride of barium. Allow the precipitated sulphate of baryta to stand aside for several hours; then filter, wash well, ignite and weigh. 233 parts of the ignited sulphate of baryta contain 32 parts of sulphur.

Fixed Carbon.—On heating the coal to obtain the percentage of volatile matter, part of the sulphur is volatilized, part is burned off with the fixed carbon, and part remains in the ash. Except in special cases where separate tests are made to determine how much of the sulphur has been volatilized, it is customary to deduct the combined percentages of water, volatile matter, sulphur, and ash from 100·00, and to consider the difference as "fixed carbon."

OPENING A COLLIERY.

The location of the surface plant and the colliery opening depends on the formation of the coal-deposit primarily, and secondarily on the facilities for transporting the product to market. It is impossible for one not on the ground and unfamiliar with natural or railroad transportation facilities in the neighborhood to give an idea as regards the secondary consideration. As regards the primary consideration, the following observations will be found of value:

When the coal outcrops within the limits of the property and is flat, a water-level drift is the best method of opening it. If the coal has any considerable inclination, it should be opened by a slope, or by a tunnel driven across the intervening measures.

In the Bituminous fields, where the seams have an inclination of but from $\frac{1}{10}$ of 1° to 1¼°, the water-level drift is generally used, and the main haulage entry is opened at the lowest accessible point on the outcrop, which ensures free drainage and a favorable grade for haulage. When the outcrop coal dips into the hill, the drift is usually commenced a few feet below the coal-terrace, and driven on a slight up-grade until the normal dip is reached.

When the inward dip is too strong, the better plan is to sink a shaft in the center of the basin, provided the depth is not too great and the amount of water to be pumped is comparatively small. If the inward dip to the center of the basin does not exceed a total of 25 ft. difference in level, a drift may be used and drainage be effected by a syphon.

In the Anthracite regions water-level drifts are only profitable where the inclined seam is exposed in ravines or gorges eroded across the strike of the measure, or where the vein can be reached by a short tunnel from the surface to the vein across the measures. This is often the case when the vein dips with the hill, but when the dip is against the hill, the tunnel is generally a long one. While the expense of operating a mine opened by a long tunnel is less than one opened by a slope or shaft, owing to cheaper drainage and haulage, when the coal above water-level is exhausted the tunnel is almost

worthless. When the seam is inclined and is accessible at no point along its outcrop low enough to furnish sufficient lift or breast length, it should be opened by a slope or shaft. Or, if the seam is flat and does not crop on the tract, a shaft is the only method of working it, unless it lies so near the surface that it can be stripped.

Where a seam has a dip of 20° or more, and is brought close to the surface by an anticlinal axis or "saddle," a "rock slope," or, in other words, a tunnel dipping the same as the coal may be started from the surface, and when the seam is reached may be continued to the desired depth in the coal. In sinking slopes it is customary to sink an airway alongside of and parallel with the slope, with a pillar of about ten yards between. The slope is usually sunk so that there is a "lift" of from 100 to 110 yds., and then gangways are turned off on each side. The term "lift" in this connection means the length on pitch that breasts or rooms, driven at right angles to the gangway, can be driven in good coal. Subsequent lifts are usually from 80 to 100 yds. long.

SHAFT-SINKING AND TIMBERING.

Shafts in America are generally rectangular in form. Indeed it is doubtful if there is a circular winding coal-shaft in the United States. They have usually three compartments, viz., two hoist-ways and a pump-way, the latter frequently being also used as an air-way.

As a general thing the loose material or wash above bed-rock is not thick enough to cause any serious trouble, and ordinary cribbing of heavy timber or a masonry curbing is sufficient. But when the surface is very thick or loose and runs like quicksand, considerable difficulty is experienced. The general method of overcoming this difficulty in the past was to at once divide the shaft into the required number of compartments by heavy timbers alternating or placed "skin to skin," which had the effect of bracing the cribbing against the lateral pressure of the loose material. This method is effectual where the wash will remain solid or stand long enough to allow the timbering and cribbing to be put in.

But, as it often happens in quicksand, the sinkers can make no progress against the treacherous element they have to contend with, other methods have to be employed. The most successful methods are the pneumatic and the Poetsch methods. The former consists of applying the caisson principle. The men work in a caisson and the loose material is kept back by compressed air forced in and held at a constant pressure. The Poetsch system consists of sinking a number of tubes in the quicksand around the outside of the shaft, and then with a refrigerating machine and compound, freezing the quicksand to a solid mass, thus forming an area of material as hard as ordinary sandstone reaching to bed-rock. In the center of this the shaft is sunk, the refrigerating process being kept up until the shaft reaches the solid rock and the lining, whether of timber, masonry, or iron, has been securely fixed in place.

The size of shafts vary greatly, depending on the number of compartments desired and the size of the compartments. They are generally from 10 to 12 ft wide inside of timbers, and each compartment is from 6 to 7 ft. wide inside the guides. This would make the outside dimensions of a double-compartment shaft about 13 to 15 ft. wide, 17 to 18 ft. long, and a triple-compartment shaft from 24 to 25 ft. long. In some instances shafts are sunk with four or six compartments.

SINKING HEAD-FRAMES.

Head-frames of very simple form are used for sinking. The skeleton of the frame is formed of heavy squared timber (10″ x 10″ or 12″ x 12″) mortised and pinned together, and braced by diagonal braces. A good height from the surface to the center of the sheave is from 20 to 25 ft. The sheave should be from 6 to 8 ft. in diameter. The sinking bucket should be of boiler-iron or of heavy hardwood strengthened by iron bands, about 3 ft. in diameter at the top by from 2½ to 3 ft. deep. It should be suspended by a handle pivoted a trifle below the center, and it should have a pin on the rim of the bucket which will hold it in an upright position when a loose ring on the handle is slipped over it. A chain fastened to the top of the head-frame, with a hook on its loose end, is suspended so that when hanging plumb it is over a schute leading to the dump-car. As the bucket is hoisted out of the shaft, this chain is attached, and the engine reversed. The bucket swings over the schute, the ring holding it upright is knocked off the pin, and the rock is dropped into the schute. Rocks too large for the

bucket are suspended in chains and are hoisted in that way; and removed on a truck that runs on a track inside of the head-frame, and of a gauge sufficiently wide to give plenty of clearance for the bucket.

SINKING-ENGINES.

Most shafts and slopes are sunk with old engines or else by engines especially designed for such work, and so constructed that they can easily be moved from place to place. In some cases where an old engine can be readily had, it is set up on temporary timber foundations and used till the shaft or slope is finished, when it is replaced by the permanent engines, and the old one is dismantled and disposed of to the best advantage.

TOOLS AND EXPLOSIVES.

The old method of hand-drilling is still adhered to in many instances, but it is gradually giving way to machine-drilling, especially in deep shafts. When properly managed the work is done much more rapidly and economically by the several excellent types of rock-drills now on the market. They are constructed in a variety of shapes by the makers, and there are so many convenient accessories in the shape of fittings, etc., that all contractors prominent in the various coal-fields possess one or more of their favorite type of drills. These drills are run either by compressed air, steam, or electric power, and in large shafts two are usually employed, so that work may not be delayed by a break-down of one drill. The center or one side of the shaft is usually kept in advance of the rest, so as to furnish a sump for the collection of the water. The holes are drilled from three to six feet apart, and the depth varies with the character of the rock. When a sufficient number of holes are drilled, the drill is removed, and a cartridge made of dynamite, dualin, or some other form of high explosive is tamped in each hole. These are all fired simultaneously by an electric battery, detonating caps being placed in each charge.

To keep the shaft the required shape, if rectangular, a plumb-bob is suspended in each corner, either from the flooring on top, or from a beam laid across the cribbing, and these guide the miner in squaring the corners and sides. If the shaft is a circular one, a plumb-line is let down in the center, from time to time, and a rod cut the exact radius is revolved around it. If it strikes the rib the miner knows that at that point the shaft is not true.

The explosives used vary in different fields. The following, however, is a list of those most generally used, with a statement of their composition:

Dynamite—75 per cent. nitro-glycerine, 22 per cent. bone-dust.

Dualin—80 per cent. nitro-glycerine, 20 per cent. nitro-cellulose.

Rendrock—40 per cent. nitro-glycerine, 40 per cent. nitrate of soda or potash, 13 per cent. cellulose, and 7 per cent. paraffin.

Giant Powder—30 per cent. nitro-glycerine, 48 per cent. nitrate of soda, 8 per cent. of sulphur, and 8 per cent. charcoal.

Vulcan Powder—35 per cent. nitro-glycerine, 48 per cent. nitrate of soda, 7 per cent. sulphur, 10 per cent. charcoal.

Electric Powder—33 per cent. nitro-glycerine. The balance is a secret.

Dessignolle Powder—50 per cent. picrate of potash and 50 per cent. nitrate of potash.

Brugere Powder—50 per cent. picrate of ammonia, 50 per cent. nitrate of potash.

Tonite—52·5 per cent. gun-cotton, 47·5 per cent. nitrate baryta.

Explosive Gelatine—89 per cent. nitro-glycerine, 7 per cent. gun-cotton nitrated, and 4 per cent. camphor.

Atlas Powder, A—75 per cent. nitro-glycerine, 21 per cent. of fibreless wood, 2 per cent. carbonate of magnesia, and 2 per cent. nitrate of potash.

Atlas Powder, B—50 per cent. nitro-glycerine, 34 per cent. nitrate of soda, 14 per cent. fibreless wood, and 2 per cent. carbonate of magnesia.

Judson Powder, No. 1—17·5 per cent. nitro-glycerine; the rest unknown.

Judson Powder, No. 2—14 per cent. nitro-glycerine, 59·9 per cent. nitrate of soda, 13·5 per cent. sulphur, and 12·6 per cent. pulverized cannel coal.

Judson Powder, No. 3—5 per cent. nitro-glycerine, 64 per cent. nitrate of soda, 16 per cent. sulphur, and 15 per cent. pulverized cannel coal.

Rackarock—77·7 per cent. chlorate of potash, 22·3 per cent. nitro-benzol.

Gelatine Forcite—95 per cent. nitro-glycerine, 5 per cent. cellulose matter not nitrated.

Gelatine Dynamite, A—97·5 per cent. nitro-glycerine, and 2·5 per cent. soluble gun-cotton.

Gelatine Dynamite, B—75 per cent. nitrate of potash, 24 per cent. cellulose matter, 1 per cent. soda.

Gelignite—56·5 per cent. nitro-glycerine, 3·5 per cent. nitrated cotton, 8 per cent. wood bark, 32 per cent. nitrate of potash.

Melinite—Picrated acids, cellulose matter dissolved in ether.

Roborite—Nitrated napthaline and nitrate of potash.

In this connection it is well to also note the fact that in some instances shafts in this country have been sunk in which all the holes for blasting were driven from the bed-rock to the coal by diamond drills. The holes, when completed, were filled with sand, and when blasting commenced the miners took out from three to four feet of this filling, and fired them in groups. A central group of holes was fired first and the outer rows afterwards. It was surprising to note how little squaring up was afterwards necessary when this system was used. The above, however, only applies to shafts of not over 100 yards in depth. When the depth is greater than this it is advisable to bore only two or three hundred feet, sink to that depth, and again set up the drills for another stage of drilling, because the diamond drill, particularly when boring a hole of small diameter, is liable to deflect from a true perpendicular.

The *Kind-Chaudron* process of shaft-sinking consists essentially of the oil-well method of drilling on a mammoth scale, and has never been used to any great extent.

THE TIMBERING OF SHAFTS.

When the shaft is through rock that from its solid nature makes timbering unnecessary, it is divided into compartments by heavy single timbers placed five or six feet (vertically) apart. To these the cage-guides, usually of straight-grained yellow pine, or oak, are fastened by bolts with countersunk heads. These timbers are set in notches or steps cut in the sides of the shaft, and they are fastened tightly in place by wooden wedges.

When the sides of the shaft are not self-sustaining, complete timbering is necessary; the distance between each set of timbers depending, of course, on the nature of the sides.

Various forms of joints or mortices are used, but the strength of the timbers should never be impaired by the removal of too much wood, or a tendency to split caused. Wedge-shaped joints and dovetailing are, for this reason, bad joints.

When the sides are very unsafe, lagging or plank-sheathing should be placed between the timbers and the rock. For this purpose iron plates are sometimes used, and in circular shafts in Europe, iron "tubbing," which consists of segments of a cylinder, bolted together, or of complete cylinders of proper diameter, lowered into the shaft and bolted together, are used.

When the sides are giving off a considerable amount of water, and timber is used for lining, another cribbing outside the regular cribbing, backed with three-inch plank, should be put in, and the space tightly rammed with clay filling. The thickness of this clay filling must be determined by the nature of the sides, but it should never be less than 12 inches.

The following cuts illustrate good standard joints for shaft-timbering:

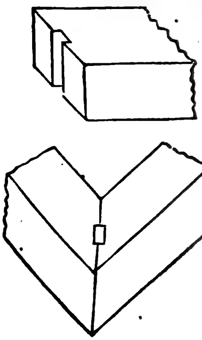


Fig. A.

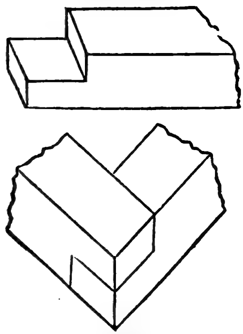


Fig. B.

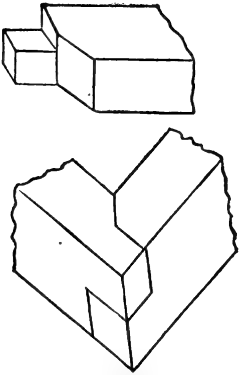


Fig. C.

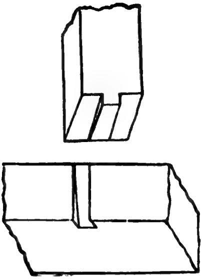


Fig. D.

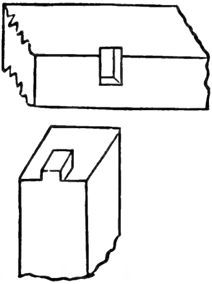


Fig. E.

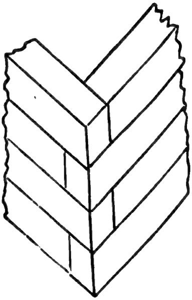


Fig. F.

Fig. A shows a mitre-joint with a key. This style of joint is a good one if properly and carefully made. But unless the joint is properly fitted, it has a wedging effect and splits the timbers.

Fig. B shows the half-check joint.

Fig. C shows a combination of the principles of the mitre and half-check joint; but it requires careful fitting to make it effectual.

Figs. D and E show timbers tongued into grooves.

Fig. F shows timbers squared and driven tightly in place. This style is often merely fastened by spiking together. In some cases they are hung by bolts, but the more common plan is to support them on square pieces of timber spiked into the corners and under the joints.

DRAINAGE AND VENTILATION.

When only a small amount of water is encountered while sinking, the best plan is to allow it to collect in a depression and bail it from there into the bucket, and hoist it the same as the rock. Where the water is excessive in quantity, a steam-pump is necessary. All of the leading pump-works make pumps especially designed for sinking purposes, and it is not the province of this work to mention the advantages possessed by one over the other.

When the shaft is of moderate depth, a fire burning in one corner will supply ample ventilation. To rapidly clear away smoke, a good plan is to burn a bundle of straw or shavings in one end of the shaft, and throw a couple of buckets of water down the other end. When the shaft is very deep,

or when the sectional area is small, ventilation is produced either by a steam-jet, or by a small fan turned either by steam or by hand. In some cases a fire is used, that draws into a board pipe.

SPEED AND COST OF SINKING.

Any attempt at a general estimate regarding the speed and cost of sinking is impossible for many reasons appreciated by the practical miner. Shafts vary in size, and in the character of the material through which they pass, so much that even if there were no other items to be considered, a general estimate could not be made. But, if the ground is pretty well known, and the sectional area and the depth given, the experienced contractor knows how much he can drive in a given time, and he can consequently form a good estimate for each separate shaft. The range of cost is so great that it may be anywhere from $1.00 to $10.00 per cubic yard of material excavated.

SLOPE-SINKING.

A slope is an inclined plane driven down on the bed of the seam, and is generally through coal, though sometimes they are driven through rock, across measures to cut the coal in a seam that can not be conveniently worked by a slope in the coal. In the latter case it is merely an "inclined tunnel." In the former it might be termed an "inclined gangway."

A slope and an inclined plane, when mentioned hereafter, will mean an inclined opening *in coal*, used as a passage-way for mine-cars.

When the location of the slope has been decided on, the first thing to be done is to erect a temporary sinking-plant. For this purpose an old engine is generally used. For a short distance, varying with the nature of the ground, but usually ranging from ten to twenty feet on the pitch, an open cut is made, and the earth, rock, or crop coal is thrown out by hand. As soon as sufficient cover is reached the work of undermining and timbering is commenced, and at the same time a double or single track is laid, so that the coal can be taken out in a car or self-dumping skip. When the latter is used, the track is continued up a trestle some distance above the surface, and a head-sheave so placed as to draw the skip up the required distance and dump the material in a shute beneath the trestling.

The width of the slope depends on the size of the cars, and the number of compartments. The most common arrangement is to divide the slope into three compartments; two large ones for hoistways and a smaller one for pump-rod, column-pipe, steam-pipe, and traveling-way. This latter is also used while sinking is going on, as an air-way.

In some instances slopes have but one hoist-way, laid with three rails and a turnout at the middle of the hoist, and some have single track with a central turnout. This may be economy in first cost, but is not in the long run. Collisions are apt to occur, and the breaking of a rope or the falling of coal from an ascending car is apt to cause more damage than when two compartments are used.

When several lifts are simultaneously worked, a single-track slope is used; but, unless the pitch is light and several cars can be hoisted at once, this method produces a comparatively small output.

When the dip of a slope is under 40° the height of the slope should be about 7 ft. in the clear. When the slope dips more than 40°, unless self-dumping skips or gunboats are used, a cage is necessary, and then the height must be made greater.

The sinking of a slope is similar to gangway-driving, and the tracks and timbering are kept well up to the face.

The timbering is very similar to gangway-timbering, except that squared timber is more frequently used (but it is not necessary), and the joints are cut with more care. On steep pitches a heavy "mud-sill" is let into the rib on each side to prevent the road from slipping down the pitch.

The following figures show various methods of slope-timbering:

Fig. 1.

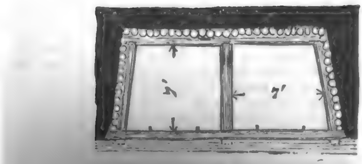


Fig. 2.

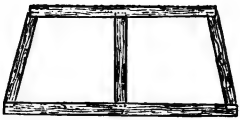


Fig. 3.

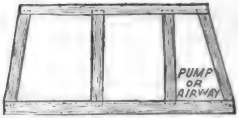


Fig. 4.

Fig. 1 shows a slope with no other timbering but a center prop.

Fig. 2 shows legs, collar, and center prop of round timber, with lagging on sides and top.

Fig. 3 shows square timber for a slope with two compartments.

Fig. 4 shows square timber for a slope with three compartments.

Fig. 5 shows a ground-plan of the arrangement of mud-sills, legs, center props, and road-bed.

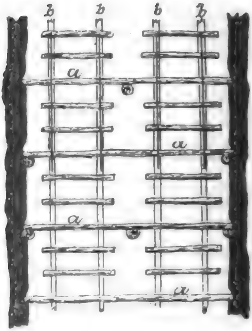


Fig. 5.

The mud-sills represented by *a* should be about 6 ft. apart, from center to center. The braces, *b*, are used to keep the sleepers in place. It will be noticed on the plan that the upper mud-sill is set into the rib at each end and rests against a prop in the center; the next rests against props at each end, and has no support in the center; the third is supported both at the ends and center by props; and the last is merely supported by shoulders cut in the ribs. This gives the plan to be adopted when any style of timbering, or when no timbering, is used.

The props and timbers should be inclined slightly (from two to five degrees) up the pitch, and not set perpendicularly to the top and bottom, as in gangway work. This rule applies also to the timbering or propping of any inclined opening.

In some cases, when square timber is used, the lining for top and sides is either made of planks or slabs. Square timber for slopes should be at least 12″ x 12″. When round timber is used, especially if there is no center prop, it should be at least 15″ in diameter. When a center prop is used it should not be less than 12″.

THE SUMPT.

When the shaft or slope is completed, among the first things necessary is a sumpt in which to collect the drainage of the colliery. This is an opening lower in the vein, when it is a pitching one, or in the rock when it is a flat seam reached by a shaft. It should be large enough to hold any excess of water that the pumps cannot handle; and the pumping machinery should be powerful enough to handle the ordinary drainage by running not over ten hours per day. When this is the case, in an emergency the pumps can be run continuously, and thus handle the surplus water.

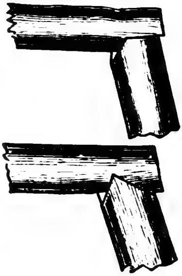
DRIVING THE GANGWAY.

In Bituminous seams the height of the gangway is governed by the thickness of the seam, and this is also true in a certain sense in the Anthracite regions. But in the Anthracite regions they are very seldom less than six feet in height. In the larger veins they are from 6′ 6″ to 7′ 6″ high, in the clear, and from ten to fifteen feet wide. The gauge of track varies from 24″ to 48″. The grade should rise at least 4″ in 100 ft., and a gutter three ft. wide by eighteen inches deep should be cut in the coal on the low side. This gutter should be a *gutter*, and not a receptacle for refuse. There is no economy in a shallow gutter, or in neglecting it because it costs a few cents a day to keep it open. Some authorities advise a rise of from six inches to a foot in every hundred feet, but they evidently do not take into consideration that so great a rise means a loss of from twenty-six to fifty-three feet in lift at the end of a gangway a mile long, or in other words, in the loss of from 68,000 to 137,000 sq.

ft. of the area of coal to be reached by the gangway. This applies to pitching seams. Where the seam is flat, or nearly so, the gangway must, of course, be driven on a grade that best suits the formation. Turnouts constructed on each side of the shaft or slope of a suitable length are a necessity if the slope or shaft is to be kept constantly supplied with coal. These turnouts vary in length, depending on the length of the cars, and the number necessary to keep the machinery in motion between trips. They should be wide enough to allow at least three feet in the clear between the bodies of the cars. Five feet is even better. When possible to avoid it, there should be no center props between the tracks.

Gangway timbering depends on the nature of the roof, sides, and pitch of seam. It is intended to protect the workings and miners from falls of *loose* pieces, and is not intended as a support for the overlying strata.

In some instances no timber is necessary; in others double timber is required. In still others, what is known as post-and-bar timbering is used. Two of the best forms of joints for double timbers are shown in the annexed sketches.



The post-and-bar system is not a good one, and is not used to any great extent. In standing a prop, cut a round foothold, deep enough to reach the solid; throw a handful of fine dirt in the hole, and twist the prop around in it several times; this beds it and gives the end full bearing-surface. The bottom of the prop should be dressed like the frustum of a cone. The length should be measured accurately, so that when it is driven as tight as possible it will be nearly at right angles to the dip. The butt-end should be against the top because it presents more bearing-surface; and between it and the top there should be a cap-piece of three-inch plank. Care should be taken to get the prop in so that the pressure is distributed equally over the whole surface of the top. The practice of driving wedges, either between the prop and cap-pieces, or between the cap-piece and the top, is a bad one, and puts the weight on one corner, and thus detracts from the strength of the prop. The weight should always come squarely, or very nearly so, on the prop, and not diagonally.

METHODS OF WORKING.

There are two general methods of working the coal, viz.: by Bord and Pillar (breast and pillar) and by Longwall. There are combinations of the two systems, and also modifications of each, which, of course, depend upon the characteristics of the vein and strata. Longwall is suitable for seams lying at any angle, but is most successfully used in seams dipping less than 25 degrees. Bord and Pillar is also suitable for seams lying at any angle, but is preferable in seams dipping over 25 degrees.

In soft seams, when the roof crushes, the wall-face should be perpendicular to the cleat, and in strong seams parallel to the cleat. Its proper position is more dependent upon the inclination of the seam than upon the direction of the cleat, and the following general rules should be observed:

If the inclination of the seam is moderate, the wall-face should be perpendicular to the dip, when the roads will be easy to maintain, and a level course is obtained in the face.

Where the dip of the seam is considerable, the wall-face should be parallel to the direction of dip, when the principal roads for bringing down the coal will be cross-cuts, which can be worked likely as self-acting inclines. The stalls will be very short not more than 5 yards long each This method prevents accumulation of gas in the face, which would result if the wall-face were perpendicular to the rise of the seam.

In Bord and Pillar working the size of pillars depends on the depth of the seam from the surface.

In his "Winning and Working of Collieries," Mr. Dunn gives the following scale for first working, with the design of afterwards taking out the pillars, the width of the principal workings being 5 yards, and cross-holings 2 yards.

Depth in Feet.	Size of Pillars in Yards.	Proportion in Pillars.	Depth in Feet.	Size of Pillars in Yards.	Proportion in Pillars.
120 ...	20 by 5 ...	·41	1080 ...	26 by 14 ...	·69
240 ...	20 " 6 ...	·50	1200 ...	26 " 16 ...	·71
360 ...	22 " 7 ...	·52	1320 ...	28 " 18 ...	·73
480 ...	22 " 8 ...	·57	1440 ...	28 " 20 ...	·75
600 ...	22 " 9 ...	·59	1560 ...	30 " 21 ...	·77
720 ...	22 " 12 ...	·61	1680 ...	30 " 22½ ...	·78
840 ...	26 " 15 ...	·63	1800 ...	30 " 24 ...	·79
960 ...	28 " 16 ...	·66			

In the following table, the weight thrown upon pillars at different depths by the removal of different proportions of coal is given.

Depth of Seam in Feet.	Weight on Pillars, the proportion to mine got being								
	90 per cent. Lbs. per sq. in.	80 per cent. Lbs. per sq. in.	70 per cent. Lbs. per sq. in.	60 per cent. Lbs. per sq. in.	50 per cent. Lbs. per sq. in.	40 per cent. Lbs. per sq. in.	30 per cent. Lbs. per sq. in.	20 per cent. Lbs. per sq. in.	10 per cent. Lbs. per sq. in.
100	111	125	142	166	200	250	333	500	1,000
500	555	625	710	830	1,000	1,250	1,665	2,500	5,000
1,000	1,111	1,250	1,428	1,666	2,000	2,500	3,333	5,000	10,000
1,500	1,666	1,875	2,138	2,496	3,000	3,750	4,998	7,500	15,000
2,000	2,222	2,500	2,956	3,333	4,000	5,000	6,666	......	......
3,000	3,333	3,750	4,384	4,999	6,000	7,500	......	......	......
4,000	4,444	5,000	5,912	6,666	8,000	......	......	......	......
5,000	5,555	6,250	7,340	......	......	......	......	......	......
10,000	11,110	12,500	......	......	......	......	......	......	......

In his "Notes and Formulæ for Mining-Students," Mr. J. H. Merrivale, in contrasting the two systems, says:

In Longwall, a face of considerable width, say 100 to 500 yards, is opened out, and the coal is worked along the whole distance either in one lift or in steps. The roads—main-gates and cross-gates, as they are called—pass through the goaf and are supported on packs built up of the stone taken down to form height in the roads. The roof along the face is also supported on packs made from the refuse of the seam, and where this fails, on timber which is drawn and shifted forward as the face advances. All superfluous stone, &c., not required for the packs, is cast back into the goaf, and one of the main elements of success in this system of working is that there should be sufficient of this to fill, more or less completely, the void left by the abstraction of the seam, so as to let down the roof evenly and gradually.

In Bord and Pillar the seam is first cut up into rectangular masses by two sets of excavations, driven at right angles to one another, and then these masses are removed in slices about four to seven yards wide. The first operation is called working in the "Whole Mine," and the second working in the "Broken."

Longwall then may be defined as any system of working in which the seam is removed at one operation: Bord and Pillar, as any system in which the seam is removed by two or more series of workings.

The Bord and Pillar and Longwall systems of working are adapted to different circumstances, so that an exact comparison is impossible, though a general one may be made as follows:

1. *Ventilation.*—In Longwall the air enters by the main gate, and, dividing into two splits, passes along the face, returning by roads on the extreme right and left. Nothing can be simpler than this arrangement; very little brattice is required, and the air, having the shortest possible distance to travel, acquires the least possible heat from the strata, a matter of great importance in deep mines, and also requires the least possible ventilating-pressure (*i. e.*, less expenditure of money) to set it in motion.

In Bord and Pillar the air also enters by the central drift or mother-gate bord, and divides into two splits; but, as the air has to be taken into each bord, it has a very much longer distance to travel, and a great deal of brattice is required.

On the other hand, should there be much gas, it can be isolated to the bord in which it is being given off in Bord and Pillar; whilst in Longwall it will foul the whole face on the inbye side.

2. *Produce.*—In Longwall all the seam may be extracted, and whilst the weight of the roof helps to break down the coal at the face, it does not rest upon it ong enough to crush the coal. This, combined with the small amount (if any a all) of nicking and narrow work, tends to the production of the maximum of round coal

In Bord and Pillar all the seam cannot be extracted, as some coal must always be left in stooks, and in addition, a portion of the pillars is often lost by falls of roof. In the whole workings, small coal is produced by nicking and narrow work and often in the broken by crush. The result being a smaller production both of unscreened and of round coal than in the Longwall method of working.

3. *Cost.*—In Longwall the cost of putting, supervision, and materials (*i. e.*, rails, sleepers, and brattice) will be less than in Bord and Pillar because the distance is shorter; and, as there is no yard work, and the weight of the roof helps to bring down the coal, the cost of hewing also will be less. On the other hand, shift and stone work will be very expensive, so much so, that where powder cannot be used, Longwall is, in many cases, inadmissible.

A given length of face will stow more men in Longwall than in Bord and Pillar.

4. *Surface Damage.*—When it is intended to work out the whole of the seam less damage is done by Longwall than by Bord and Pillar, because the space formerly occupied by the seam is filled up by the stowage, and though this cannot be done so completely as to support the weight of the superincumbent strata without considerable compression of the stowage, yet the character of the support is the same over the whole area, and the surface is let down gradually and uniformly.

In Bord and Pillar the surface damage usually takes the form of irregular depressions dotted about here and there, putting a stop to all farm drainage.

5. *Accidents.*—Accidents from falls ot stone are less likely to happen in Longwall than in the broken workings of Bord and Pillar; and, as no coal is left below ground, underground fires, from the spontaneous combustion of small coal crushed and ground together by falls of roof, are impossible. On the other hand, gas cannot be isolated to the place where it is being given off, as in Bord and Pillar. And in Longwall, the men being closer together, should an explosion occur, more are likely to be killed.

Summary.—Longwall is suitable for thin seams (less than four feet) or very thick (more than twelve feet) seams, lying at any angle; especially when they produce sufficient refuse for stowage and contain no gas and few troubles.

Bord and Pillar is suitable for seams of moderate thickness (from $3\frac{1}{2}$ to 8 feet) lying at low angles, especially if there be gas and troubles.

WORKING OF ANTHRACITE SEAMS.

HINTS FOR LARGE SEAMS WHEN THE COAL IS SOFT AND SHELLY OR SLIPPERY, AT AN ANGLE OF MORE THAN 50°, AND GENERATING LARGE QUANTITIES OF FIRE-DAMP.

The great danger to be guarded against is the sudden liberation of gas should a breast "run," that is, should the coal at the face loosen and run out by its own gravity, only stopping when it chokes or fills up the open space below. To meet these conditions, the air-course may be driven above the gangway and used as a return, the fan being attached as an exhaust, and the working-breasts ventilated in pairs. The inside man-way of one of a pair of breasts is connected with the gangway for the intake and the outside man-way of the other breast with the return air-way, giving each pair of breasts a separate split of the current. In collieries where this system of working is followed the coal is soft. A new breast is worked up a few yards, but as soon as it is opened out, the coal runs freely and the man-ways are pushed up on each side as rapidly as possible, to keep up with the face. The two miners, one on either side, sometimes finish a breast without being able to cross to each other. The work is done exclusively with safety-lamps, and when a breast "runs" the gas is liberated in such quantities that it frequently fills breasts from the top to the air-way before the men can get down the man-way on the return side. When the gas reaches the cross-hole, it passes into the return air-way without reaching any part where men are working. Should a "run" of coal block a breast by closing the man-way it affects the current of one pair of breasts alone. As the gangway is the intake, leakage at the batteries passes into the breasts, as the cross-holes are above their level and the gas is thus kept above the starter when at the draw-hole. The gangway, chutes,

and air-way are supplied by wooden pipes, which connect with a door behind the inside chute. If a breast runs up to the surface, it does not affect the return air-way, as it is in the solid.

Among the disadvantages urged against this system of working are the following:

It increases the friction, as the air must pass in the air-way all the distance from the breast to the fan, the area of the air-way being small in comparison to the gangway or intake.

As the faces of the breasts are so much higher than the return air-way, the lighter gas must be forced down into the return against the buoyant power of its smaller specific gravity.

The reduction of friction obtained by splitting is neutralized by each split running up one small manway and down another; the advantage of running through several pillar headings and thus securing a shorter course being lost. This can be partly obviated by ventilating the breasts in groups, but the dangers avoided in splitting are increased.

Black-damp, which accumulates in the empty or partly empty breasts, works its way down and mixes with the intake current, as there is no return current in the breast strong enough to carry it away, the return being closed in the air-way.

All things considered, when the seam is soft and has a pitch of 40° and upward, and emits large quantities of gas in sudden outbursts, as in running breasts, this system is the best that can be adopted.

WHEN THE COAL IS HARD AND GAS IS NOT FREELY EVOLVED.

The reverse of the system just described is followed at some collieries where the coal is hard and but little gas is encountered. The air-way is driven over the gangway or against the top, the fan being used to force the air inward to the end of the air-way. The air is distributed as it returns, being held up at intervals by distributing doors placed along the gangway.

Among the advantages claimed for this plan are the following:

As the pressure is outward, it forces smoke and gas out at any openings which may exist from crop-hole falls or other causes.

The warm air from the interior of the mine returning up the hoisting-slope or shaft prevents it from freezing.

As the current is carried from the fan to the end of each lift without passing through working-places, the opening of doors as cars are passing, &c., does not interfere with the current.

If a locomotive is used, the smoke and gases generated by it are carried away from the men toward the bottom. Locomotives are generally used only from the main turnout to the bottom.

An objection to this system is that the gangway, as the return, is apt to be smoky. Starters and loaders are forced to work in more or less smoke, and even the mules work to disadvantage, while if gas is given off, it is passed out over the lights of those working in the gangway.

However, in places where there is but little gas, and air-ways of large area can be driven, this plan works very satisfactorily, and some of the best-ventilated collieries are worked upon it.

An objection advanced by some against forcing-fans is that they increase the pressure, thus damming the gas back in the strata. In case the speed of the fan is slacked off, the accumulated gas may respond to the lessened pressure and spring out in large volumes from its pent-up state. This argument, however, works both ways. An exhaust fan, running at a given speed, is taking off pressure, and if anything occurs to block the intake the pressure is diminished, and the gas responds to the decrease upon exactly the same principle.

HINTS FOR THE SMALLER SEAMS WHEN THEY ARE SMALL AND LAY FROM HORIZONTAL TO ABOUT 10°.

Two gangways may be driven, the lower or main gangway being the intake. Branch gangways should then be driven diagonally or at a slant, with a panel or group of working-places on each slant gangway. Large headings should connect the panels. In this system the air is carried directly to the face of the gangway and up into the breasts, returning back through the working-places. The intake and return are separated by a solid pillar, the only openings being the slant gangways on which are the panels.

The advantages of this plan are several:

The main gangway is solid, with the exception of the small cross-holes con-

necting with the gangway above; these furnish air to the gangway and are small and easily kept tight. These stoppings should be built of brick, and made strong enough to withstand concussion.

A full trip of wagons can be loaded and coupled in each panel or section without interfering with or detaining the traffic on the main road; one trip can be loaded while another is run out to the main gangway for transportation to the bottom.

The only break in the intake current is when a trip of cars is taken out from or returns to a panel or section; this can be partially provided against by double doors, set far enough apart to permit one to close after the trip before the other is opened. This distance can be secured by opening the first three breasts on a back-switch above the road through the gangway-pillar, or by running each branch over the other far enough to obtain the distance for the double doors.

If it is not desired to carry the whole volume of air to the end of the airway, a split can be made at each branch road. These will act as unequal splits in reducing friction, and although not theoretically correct, are preferable to dragging the whole current the full length of the workings.

The objections urged to this plan are:

That it involves too much expense in the large amount of narrow work at high prices necessary to open out a colliery; that it necessitates a double track the whole length of the lift, and that the grade ascends into each panel or section. But the latter criticism falls, because the loss of power hauling the empty wagons up a slight grade is more than made up by the loaded wagons running down, while the mules are away putting a trip into another panel or section.

For a large colliery this is, without doubt, the best and cheapest system.

WHEN THE SEAM IS SMALL AND LIES AT AN ANGLE OF MORE THAN 10°.

In small seams lying at an angle of more than 10°, and too small to permit an air-way over the chutes, it is more difficult to maintain ventilation. If air-holes are put through every few breasts, and a fresh start obtained by closing the back holes, or if an opening can be gotten through to the last lift as often as the current becomes weak, an adequate amount of air can be maintained, because the lift worked can be used as the intake, and the abandoned lift above as the return. To ventilate fresh ground, the filling of the chutes with coal will have to be depended upon, or a brattice must be carried along the gangway. This can be done for a limited distance only, as brattice leaks too much air. As a rule, collieries worked upon this plan are run along until the smoke accumulates and the ventilation becomes poor; then a new hole is run through and the brattice removed and used as before for the next section. This operation is repeated until the lift is worked out. Sometimes, to make the chutes tight, canvas covers are put on the drawholes, but, as they are usually left to the loaders to adjust, they are often very imperfectly applied. Then, as the coal is frequently very large, the air will leak through the batteries.

This plan works very satisfactorily if the openings are made at short intervals, say as frequent as every fifth breast, but the distance is usually much greater to save expense. As the power of the current decreases as the distance between the air-holes is increased, good ventilation is entirely a question of how often a cut-off is obtained.

An effective ventilation could be maintained in a small seam at a heavy angle by working with short lifts, say two lifts of fifty yards instead of one of a hundred, as at present. The gangways should be frequently connected, and one used as an intake and the other as a return. This would necessitate driving two gangways where one is now made to do, but the additional expense would be made up in the greater proportion of coal won.

SPECIFIC GRAVITY AND WEIGHT OF COAL.

To determine the specific gravity of coal, take a small piece of coal, suspend it by means of a horse-hair from the under side of the pan of a carefully-adjusted balance, and weigh it both in and out of water; divide its weight in the air *by the loss of weight* in the water, and the quotient is the specific gravity.

Example.

A piece of coal weighs, say, 480 grains.
Loss of weight when weighed in water, 398 grains.
Then $\frac{480}{398} = 1{\cdot}206$, specific gravity of the coal compared with water at 1·000.

As a cubic foot of water weighs 1,000 oz., the weight of a cubic foot of any substance can be found by multiplying its specific gravity by 1,000.

The following table gives the weight and specific gravity of various coals:

Name of Coal.	S. G.	Weight of a Cubic Foot in Lbs.	Weight of a Cubic Yard in Tons.
Newcastle Hartley, England	1·29	80·6	·972
Wigan, 4 feet, England..................	1·2	75·	·914
Portland, England	1·30	81·2	·978
Anthracite, Wales	1·39	86·9	1·047
Eglington, Scotland	1·25	78·1	·941
Anthracite, Irish	1·59	99·4	1·193
Anthracite, Pennsylvania	1·55	96·9	1·167
Bituminous, Pennsylvania	1·40	87·5	1·054
Block Coal, Indiana	1·27	79·4	·956

PRODUCE OF BITUMINOUS SEAMS.

A ready way of finding the quantity of available coal in a given area of a seam is given by W. Fairley, M. E., of England. He takes an acre of coal one inch thick to contain 100 tons. This leaves a sufficient margin for faults and loss of working. Thus, a vein of coal twenty-four inches thick will yield 2,400 tons per acre.

To ascertain the exact quantity of coal under a given area—presuming the seam to be of regular thickness and quality throughout—find the specific gravity; then, as this represents the weight of a cubic foot in ounces, it is simply a matter of calculation to obtain the gross weight.

The exact weight of coal-seams can be got from the table below:

Specific Gravity.	Weight in the Natural Bed, per Acre per Inch Thick, in Tons.	Weight of a Cubic Foot in the Broken State, in Lbs.	
		Large Coal.	Small Coal.
1·10	111·411	42·62	37·12
1·15	116·475	44·56	38·81
1·20	121·540	46·50	40·50
1·25	126·604	48·43	42·18
1·30	131·668	50·37	43·87
1·35	136·732	52·31	45·56
1·40	141·796	54·25	47·25
1·45	146·860	56·18	48·93
1·50	151·925	58·12	50·62

The weight of coal in its broken state, that is, as it comes to the surface in cars or otherwise, will depend on its mechanical structure; it has been ascertained by experiment with bituminous coal in England that, as brought to the surface, it weighs, if large, in proportion to the solid coal as 62 is to 100, and the weight of the small as 54 is to 100.

If, then, the figures in the second column be multiplied by the number of inches any bituminous coal-seam is in thickness, the result will be the contents per acre in tons.

TABLE SHOWING THE NUMBER OF TONS OF COAL UNDER A SQUARE MILE AT DIFFERENT THICKNESSES.

Feet.	Tons.	Feet.	Tons.
1	972,320	9	8,750,880
2	1,944,640	10	9,723,200
3	2,916,960	20	19,446,400
4	3,889,280	30	29,169,600
5	4,861,600	40	38,892,800
6	5,833,920	50	48,616,000
7	6,806,240	60	58,339,200
8	7,778,560	70	68,062,400

PRODUCE OF ANTHRACITE COAL-SEAMS.

In making calculations upon the net product—or amount of prepared coal that can be shipped from a given area of an anthracite coal-seam—allowance must be made for the loss in mining and in preparation. This allowance will

vary with the seam, and will be far larger in the Mammoth seam than in those which are not so thick. The result of experience in the anthracite region appears to be that the larger the seam the smaller, proportionally, is the amount of coal saved.

Mr. Joseph S. Harris, in his report on the value of the coal-lands belonging to the Philadelphia & Reading Coal and Iron Company, in 1880, estimated that 27% of the contents of all the seams on the company's estate was all that could be shipped to market. Improved mining methods, stricter economy in preparation, and the utilization of the smaller sizes, enables this percentage to be greatly increased, and in some instances as high as 65% of the coal in the vein is shipped. This large percentage is, of course, in exceptional cases. An average of 45 to 50% is about right for the amount shipped at this date.

Mr. Pratt, of the Pennsylvania Geological Survey, thus summarized the data collected on "Breaker Waste":

The breaking and screening by hand in the old-fashioned way lost 6·28%; by the present breaker and screens, 15·27%; so that the breaker is to be held chargeable with extra loss over the old style of 9%.

With reference to waste in the preparation of Anthracite coal, Mr. Joseph S. Harris, who has made experiments with the "old style" rollers, or those with cast-iron teeth, and the "new style" or those with movable steel teeth inserted in a cast-iron body, says, with the "new style" there is a direct saving of from 3 to 5½% in breaker-waste, bringing down the percentage in preparing the product of the Baltimore or Mammoth seam to an average of 12%.

SPECIFIC GRAVITY AND WEIGHT OF PREPARED ANTHRACITE COAL.

To Mr. Irving A. Stearns, the General Superintendent of the Pennsylvania Railroad Company's Coal Department, we are indebted for the following summary of tests made by the mining engineers of the company.

In a series of tests to ascertain the specific gravity of the coal from different seams worked by the company, it was found that the average specific gravity was 1·4784, and the average weight per cubic foot was 92·50 lbs. This was calculated for space filled at breaker without settling. Add 5% for packed spaces or large heaps.

TABLE SHOWING WEIGHT PER CUBIC FOOT OF SUSQUEHANNA COAL COMPANY'S WHITE ASH ANTHRACITE COAL.

Size.	Size of Mesh.		Weight per Cubic Foot. Pounds.	Cubic Feet from 1 Cubic Foot Solid.
	Over.	Through.		
Lump	4½″ to 9 ″	....	57	1·614
Broken	2⅜″ to 2⅞″	3¼″ to 4½″	53	1·755
Egg	1¾″ to 2¼″	2⅜″ to 2⅞″	52	1·769
Large Stove	1¼″ to 1⅞″	1¾″ to 2¼″	51½	1·787
Small Stove	1 ″ to 1¼″	1¼″ to 1½″	51¼	1·795
Chestnut	⅝″ to ¾″	1 ″ to 1¼″	51	1·804
Pea	⅜″ to ⅝″	⅝″ to ⅞″	50¾	1·813
No. 1 Buckwheat	3-16″ to ⅜″	⅜″ to ⅝″	50¾	1·813
No. 2 Buckwheat	....	3-16″ to ⅜″	50¾	1·813

VENTILATION.

GENERAL PROPERTIES OF AIR AND GASES.

(MERRIVALE.)

Air and gases may be defined as elastic fluids in contra-distinction from liquids, which are inelastic fluids.

The elasticity of the air is used to determine the ventilating-pressure in a mine by means of the water-gauge.

Air and gases are ponderable, that is to say, they have weight; but the weight of a given volume depends upon its pressure and temperature.

Pressure.—The weight of a given volume of any gas varies as the pressure. In order to find the pressure of the air, we use the barometer.

The standard atmospheric pressure at 32° Fahr. and sea-level = 29·922 in. mer. = 14·696 lbs. per sq. in. = 2,116 lbs. per sq. ft. = 26,213 ft. of homogeneous air-column = 33·9 ft. of water-column.

To reduce a barometer reading at any point above sea-level to the corresponding reading at sea-level, the following approximate rule is given by Mattieu Williams in "Science in Short Chapters":

To the observed reading add 0·1″ for each

85 ft. up to 510 ft. that the point is above sea-level.
90 ft. from 510 to 1,140 ft.
95 ft. from 1,140 to 1,900 ft.
100 ft. when above 1,900 ft.

Thus, 28″ at a point 2,000 ft. above sea-level = 30·2″ at sea-level.

Correction for Temperature.—Mercury expands about 0·0001 of its volume for each degree Fahr. To reduce, therefore, a reading at any temperature to the corresponding reading at the standard temperature of 32°, subtract $\frac{1}{10000}$ of the observed height for each degree above 32°; or, if the temperature be below 32°, add $\frac{1}{10000}$ for each degree.

Depth of pits:

If R = Reading of barometer at lower station.
r = Reading of barometer at higher station.
T = Temperature Fahr. at lower station.
t = Temperature Fahr. at higher station.
H = Difference of level in feet.

$$H = 56{,}300\,(\text{Log. } R - \text{Log. } r)\left(1 + \frac{T + t}{900}\right)$$

$$\therefore \text{Log. } R = \frac{H}{56{,}300\left(1 + \frac{T + t}{900}\right)} + \text{Log. } r.$$

More simply:

$$H = 49{,}000\left(\frac{R - r}{R + r}\right)\left(1 + \frac{T + t}{900}\right)$$

$$\therefore R = r\left\{\frac{49{,}000\,(900 + T + t) + 900\,H}{49{,}000\,(900 + T + t) - 900\,H}\right\}$$

Very roughly, the mercury rises 1 inch for each 150 fathoms of depth.

Temperature.—The weight of a given volume of any gas varies inversely as its absolute temperature. Absolute temperature = 459 + Fahr. temp.

To find the weight of a given volume of any gas at any known temperature and pressure, 459 cu. ft. of air at 0° Fahr. and bar. 1 in. weigh 1·3253 lbs. Therefore, if

V = Volume of air in cu. ft.
W = Weight in lbs.
I = Barometer in ins.
t = Temperature Fahr.

$$W = \frac{1{\cdot}3253\,IV}{459 + t}$$

To find the weight of any other gas, multiply the weight of air by the specific gravity of the gas.

Gas in Goaves.—It has been estimated that the air-space in a goaf is equal to about one-sixth of the volume of the coal extracted.

Gases enclosed in the pores of coal must be distinguished from the gases that enter into the chemical composition of coal. Sundry analyses of these enclosed, or *occluded gases* as they are called, are given in the following table:

GASES ENCLOSED IN THE PORES OF COAL AND EVOLVED IN VACUO AT 212° FAHR.

Name of Colliery.	Quality.	CO_2.	O.	CH_4.	N.	Quantity CC per 100 Grams.	Cubic Feet per Ton.
Navigation	Steam.	13·21	0·49	81·64	4·66	250	90
Dunraven	do.	5·46	0·44	84·22	9·88	218	78
Cyfarthfa	do.	18·90	1·02	67·47	12·61	147	52
Bute	do.	9·25	0·34	86·92	3·49	375	135
Bonville's Court	Anthracite.	2·62	......	93·13	4·25	555	199
Watney's	do.	14·72	......	84·18	1·10	600	216
Plymouth Iron Works	Bituminous.	36·42	0·80	....	62·78	55·9	20
Cwm Clydach	do.	5·44	1·05	63·76	29·75	55·1	19·8
Bettwys	do.	22·16	6·09	2·68	69·07	24·0	8·6

(*Thomas.*)

Transpiration of Gases.—That is to say, the passage of gases through minute tubes, such as the pores of coal.

Name of Gas.	Times for Transpiration of Equal Volumes.	Velocities of Transpiration.
Oxygen (O)........................	1·000	1·000
Air	0·9030	1·1074
Nitrogen (N).................	0·8768	1·141
Carbonic Oxide (CO)	0·8737	1·145
Carbonic Acid (CO_2).............	0·7300	1·370
Marsh Gas (CH_4)	0·5510	1·815
Ethylene (C_2H_4)...................	0·5051	1·980
Hydrogen (H)	0·4370	2·288

Practical Bearing.—Gases flow from green coal into workings. Blowers. Gases assist hewer by breaking down coal.

The Diffusion of Gases.—When two gaseous bodies are mixed together they gradually diffuse themselves through each other; so that, after sufficient time has elapsed for the purpose, whatever may have been their relative densities, they are found intimately blended; the heavier gas does not fall to the bottom, nor does the lighter one rise to the top.

RELATIVE VELOCITY OF DIFFUSION.

	Sp. G.	$\sqrt{\text{Sp. G.}}$	$\frac{1}{\sqrt{\text{Sp. G.}}}$	Velocity of Diffusion, Air being taken as unity.
Air	1·000	1·000	1·000	1·000
Hydrogen (H)	0·06926	0·2632	3·7794	3·83
Marsh Gas (CH_4)	0·559	0·7476	1·3375	1·344
Steam (H_2O)........................	0·6235	0·7896	1·2664	......
Carbonic Oxide (C O).........	0·9678	0·9837	1·0165	1·0149
Nitrogen (N).........................	0·9713	0·9856	1·0147	1·0143
Ethylene (C_2H_4).................	0·973	0·9889	1·0112	1·0191
Oxygen (O)	1·1056	1·0515	0·9510	0·9487
Sulphureted Hydrogen (H_2S)	1·1912	1·0914	0·9162	0·95
Carbonic Acid (C O_2)	1·529	1·2365	0·8087	0·812

The above table shows that fire-damp mixes with air more readily than stythe does; and fire-damp, therefore, is more easily cleared away by the ventilating current than stythe is.

FIRE-DAMP ANALYSES.

Name of Colliery.	CH_4.	N.	O.	CO_2.	H.	
Wallsend, from pipe on surface	92·8	6·9	0·0	0·3	0·0	100·0
Jarrow, Bensham Seam	83·1	14·2	0·6	2·1	0·0	100·0
Hebburn, "	86·0	12·3	0·0	1·7	0·0	100·0
Jarrow, Low Main Seam	79·7	14·3	3·0	2·0	0·3	99·3
Jarrow, ⅘ Seam	93·4	4·9	0·0	1·7	0·0	100·0
Oakwellgate, Do....................................	98·2	1·3	0·0	0·5	0·0	100·0
Hebburn, Coal 24 ft. below Bensham...	92·7	6·4	0·0	0·9	0·0	100·0

(*De La Beche and Lyon Playfair.*)

CHEMISTRY.

Compounds and Elements.—Substances may be divided into three classes:

(1.) Chemical compounds—those substances which can be split up by chemical processes into two or more different materials.

(2.) Chemical elements or simple substances—those which have hitherto resisted all attempts to split them up into two or more different materials. There are at present about 63 of these bodies.

(3.) Mechanical mixtures—substances formed from a mixture of the above.

ATOMS.

The atomic *theory* has been adopted to explain the *fact*, that in chemical combinations elements unite in fixed proportions.

An atom is the smallest particle of an element that can *enter into chemical combination* with other elements.

Atoms are incapable of being divided.

The atoms of the same substance are similar to one another and equal in weight.

The atoms of different substances differ in weight.

The weight of the atom of hydrogen being taken as the unit; the atom of oxygen weighs 16, the atom of nitrogen 14, and so on.

CHEMICAL SYMBOLS.

The atoms of the elements are represented by symbols; the first letter of the name being generally taken to express the atom.

Thus, the atom of Oxygen is denoted by O.
" Nitrogen " N.
" Hydrogen " H, etc.

These symbols represent definite weights of the respective elements. H represents the unit of atomic weight, *i. e.*, the weight of the hydrogen atom, whatever that may be.

O represents a weight of Oxygen = 16 Hydrogen atoms.
N " Nitrogen = 14 "
C " Carbon = 12 "

The symbols and atomic weights of the elements we are interested in are given in the following table:

SYMBOLS AND ATOMIC WEIGHTS.

Name of Element.	Symbol.	Atomic Weight.
Oxygen	O	16
Hydrogen	H	1
Nitrogen...	N	14
Carbon	C	12
Sulphur	S	32
Phosphorous..	P	31
Chlorine	Cl	35·5
Potassium	K	39
Sodium	Na	23
Calcium	Ca	40
Manganese	Mn	55
Magnesium	Mg	24
Iron	Fe	56
Zinc	Zn	65

MOLECULES AND FORMULÆ.

The group of atoms forming the smallest particle of a compound which can *exist in a free state*, is called its molecule; and the molecule of a compound is

expressed by putting together the symbols of the atoms which compose it. This group of symbols is called a formula.

Thus the molecule of water contains one atom of oxygen, and two atoms of hydrogen, and may, therefore, be expressed by the formula HHO. When. however, several similar atoms are present, the symbol is only written once. and a small number on the *right* of it, and *a little below*, to show how many atoms are present

Thus the formula for the molecule of water is H_2O.

When more than one molecule has to be represented a number is placed on *the left and level.*

Thus four molecules of water are represented by $4H_2O$.

The molecule of many of the elements consists of two atoms.

CHEMICAL EQUATIONS.

Chemical changes are represented by equations.

Thus, $Zn \times H_2SO_4 = H_2 + ZnSO_4$ signifies that 65 parts by weight of zinc reacting on 98 parts by weight of sulphuric acid, form 2 parts by weight of hydrogen and 161 parts by weight of zinc sulphate.

Equal volumes of all gases contain, under the same conditions, the same number of molecules, equations therefore, representing changes in which gases take part, may be read off at once in volumes

If the volume occupied by one atom of hydrogen be taken as unity, one molecule of each of the gases will occupy two such volumes. Thus:

$$CH_4 + 2O_2 = CO_2 + 2H_2O$$

may be read:

Two volumes of marsh-gas and four volumes of oxygen, form two volumes of carbonic acid gas and four volumes of vapor of water.

THE GASES.

Oxygen.—Symbol, O; atomic weight, 16.

1,000 cubic feet at 32° Fahr and bar. 30 in. weigh 89·842 lbs.

Oxygen forms by weight $\frac{8}{9}$ of water, $\frac{1}{4}$ of the atmosphere, and $\frac{1}{2}$ of the solid crust of the earth. It was discovered by Priestley in 1774 and has neither color, taste, nor smell. Oxygen is occasionally found amongst the occluded gases: but principally occurs in mines as a constituent of air. It is essential to life; but, undiluted, it is not fit to be breathed for more than a short time. It supports combustion, and substances which burn in air burn fiercely in oxygen.

It may be prepared from a mixture of potassium chlorate four parts and manganese dioxide one part, mixed together and heated. The whole of the oxygen contained in the potassium chlorate is given off, and a compound of potassium and chlorine remains.

$$\left.\begin{matrix}\text{Potassium}\\ \text{Chlorate}\end{matrix}\right\} = \left\{\begin{matrix}\text{Potassium}\\ \text{Chloride}\end{matrix}\right\} + \text{Oxygen.}$$

$$2KClO_3 = 2KCl + 3O_2.$$

The manganese dioxide is unaltered; in fact the oxygen could be obtained from potassium chlorate alone; but it is found in practice that the presence of manganese dioxide materially assists the operation.

Carbonic Oxide.—Formula, CO; molecular weight, 28.

1,000 cubic feet at 32° Fahr and bar 30 in weigh 78·305 lbs.

This gas is the result of imperfect combustion When a body containing carbon is burnt in air, each atom of carbon will combine with two atoms of oxygen to form carbonic acid gas: but, if there is not sufficient air to provide two atoms of oxygen for each atom of carbon, that is to say, if the combustion of the carbon is incomplete, carbonic oxide is formed. It has been detected in rare cases amongst the occluded gases; and is also produced by the combustion of coke, charcoal, and gunpowder; and must in many cases be one of the constituents of after-damp.

It has neither color taste, nor smell, but is exceedingly poisonous; ½% in the air, if breathed for long producing fatal results. It does not support combustion, but itself burns with a blue flame, forming CO_2. Such a proportion of this gas can be mixed with air, as to form a mixture in which lamps will burn, and at the same time its effect on persons breathing it will be speedy death. Ignorance on this point has resulted in many deaths in mines.

It may be prepared from hydrogen oxalate, treated with hydrogen sulphate. Carbonic oxide and carbonic acid are driven off, the latter of which

is removed by passing the mixture through a solution of potassium hydrate; but, as this gas is very poisonous, it is best not meddled with by unskilled persons.

Hydrogen Oxalate	+	Hydrogen Sulphate	=	Carbonic Oxide	+	Carbonic Acid	+	Water	+	Hydrogen Sulphate.
$H_2C_2O_4$	+	H_2SO_4	=	CO	+	CO_2	+	H_2O	+	H_2SO_4

Hydrogen.—Symbol, H; atomic weight 1.

1,000 cubic feet at 32° Fahr. and bar. 30 in. weigh 5·5832 lbs.

Hydrogen has neither color, taste, nor smell. It is very inflammable, burning with an almost colorless flame. If breathed in its undiluted state, it quickly causes a very disagreeable sensation; but this is due to the exclusion of oxygen from the lungs, and not to the properties of hydrogen, which is not poisonous, and may be breathed when diluted with ten times its volume of air, for a considerable time, without experiencing any ill effect.

The experiments of Meyer and Thomas show that, in an explosion of marsh-gas and air, the whole of the marsh-gas is broken up; and, if there be too little air to form carbonic acid gas and water, carbonic oxide and hydrogen are formed.

It may be prepared by treating zinc with hydrogen sulphate. The hydrogen is driven off, and the zinc sulphate is left behind.

Zinc	+	Hydrogen Sulphate	=	Hydrogen	+	Zinc Sulphate.
Zn	+	H_2SO_4	=	H_2	+	$ZnSO_4$.

Combined with carbon in the proportion of 4 parts by weight of hydrogen to 12 of carbon, it forms marsh-gas, the principal constituent of fire-damp.

Hydrogen Sulphide.—Formula, H_2S; molecular weight, 34.

1,000 cubic feet at 32° Fahr. and bar. 30 in. weigh 94·92 lbs.

Hydrogen sulphide, or sulphureted hydrogen as it is more generally called, is a colorless gas, but has a strong smell not unlike that of rotten eggs. "It is generated in small quantities in coal-mines, more especially in old worked portions, which are partly filled with water. By the action of oxygen dissolved in water, sulphates are formed; props in undergoing decomposition in water break up the sulphate of lime, and assimilate its oxygen, the sulphur seizing probably the hydrogen of the wood to form hydrogen sulphide." (Thomas's "Coal-Mine Gases, and Ventilation," p. 204.)

It does not support combustion, but is itself inflammable, forming water and sulphurous anhydride ($H_2O + SO_2$). Breathed in an undiluted state, it is fatal to life; and when diluted with ten times its volume of air, it produces sickness, giddiness, weakness, and loss of sensation.

This gas may be prepared from proto-sulphide of iron treated with dilute hydrogen chloride. Hydrogen sulphide will be given off, and iron chloride formed.

Iron Proto Sulphide	+	Hydrogen Chloride	=	Iron Chloride	+	Hydrogen Sulphide.
FeS	+	$2HCl$	=	$FeCl_2$	+	H_2S.

Nitrogen.—Symbol, N; atomic weight, 14.

1,000 cubic feet at 32° Fahr. and bar. 30 in. weigh 78·175 lbs.

Nitrogen has neither color, taste, nor smell, and is incapable of supporting combustion or animal life, but is not poisonous, causing death when breathed only by excluding oxygen from the lungs. It is found in large quantities amongst the gases occluded in some coals; but occurs principally in mines as a constituent of air.

Mixed with oxygen, it forms air, and the readiest way of obtaining it for experiment is to withdraw the oxygen by the action of some substance which has an affinity for oxygen and not for nitrogen. Phosphorus is convenient for this purpose, since it readily combines with oxygen; and the compound formed, phosphorus pentoxide (P_2O_5), is soluble in water, and is therefore quickly absorbed when the experiment is made over the pneumatic trough, leaving the nitrogen nearly pure.

Carbonic Acid Gas.—Formula, CO_2; molecular weight, 44.

1,000 cubic feet at 32° Fahr. and bar. 30 in. weigh 128·45 lbs.

Carbonic acid gas has neither color nor smell, but an acid taste. It is found in large quantities amongst the gases occluded in some coals; but is also produced in mines by the respiration of men and animals, by the burn-

ing of candles and lamps, and by the oxidation of the coal and other substances.

It extinguishes lights, and is fatal to animal life.

It may be prepared by the decomposition of marble by hydrogen chloride. Carbonic acid gas is given off, calcium chloride and water are formed in the vessel.

$$\text{Marble} + \begin{matrix}\text{Hydrogen}\\ \text{Chloride}\end{matrix} = \begin{matrix}\text{Carbonic}\\ \text{Acid Gas}\end{matrix} + \begin{matrix}\text{Calcium}\\ \text{Chloride}\end{matrix} + \text{Water.}$$

$$CaCO_3 + 2HCl = CO_2 + CaCl_2 + H_2O$$

Fire-Damp.—Marsh-gas. Formula, CH_4; molecular weight 16.

1,000 cubic feet at 32° Fahr. and bar. 30 in. weigh 45·22 lbs.

Fire-damp is a mixture of several gases, its principal constituent being marsh-gas, CH_4; but its composition varies at different collieries, as shown in a previous table; and, in addition to these gases, coal-dust is often present. It is only found in mines as an occluded gas.

Marsh-gas may be prepared by heating a mixture of sodic acetate and sodic hydrate in an iron tube. Marsh-gas is driven off and sodic carbonate is formed in the tube.

$$\begin{matrix}\text{Sodic}\\ \text{Acetate}\end{matrix} + \begin{matrix}\text{Sodic}\\ \text{Hydrate}\end{matrix} = \begin{matrix}\text{Sodic}\\ \text{Carbonate}\end{matrix} + \begin{matrix}\text{Marsh}\\ \text{Gas.}\end{matrix}$$

$$NaC_2H_3O_2 + NaHO = Na_2CO_3 + CH_4.$$

For making experiments ordinary coal-gas may be used, though it differs in composition from average specimens of fire-damp.

COMPOSITION OF FIRE-DAMP AND COAL-GAS.

	CH_4.	H.	CO.	CO_2.	C_2H_4.	N.
Fire-damp	94·0	0	0	1·0	0	5·0
Coal Gas..........	42·0	42·0	4·5	0	9·0	2·5

The exact effects of fire-damp upon combustion and animal life depend upon its composition, temperature, and density; but speaking generally, at ordinary temperatures and pressures, when mixed with 3·5 times its volume of air, it does not explode, but burns quietly; with 5·5 volumes of air it explodes slightly; and with about 9½ volumes of air the explosion is the greatest. With 13 volumes of air, it explodes feebly; with 30 volumes of air, it will show plainly on the lamp; with 50 volumes of air, it can just be detected on the lamp by a skillful observer. If breathed in an undiluted state, it would soon cause death; but, mixed with twice its own volume of air, it may be breathed for some time without ill effects.

An explosion of marsh-gas and air by volume.—(1) Suppose we have of CH_4 2 volumes.

(2) C requires $O_2 = 2$ volumes of oxygen, forming 2 volumes of CO_2.

H_4 also requires $O_2 = 2$ volumes of oxygen, forming 4 volumes of H_2O.

(3) CH_4 ∴ requires 4 volumes of oxygen. But 1 volume of air contains ·21 volumes of oxygen.

∴ 19 volumes of air will be required for 4 volumes of oxygen.

∴ 9½ volumes of air are required for 1 volume of CH_4.

And the composition of the after-damp is 1 volume CO_2 + 2 volumes H_2O (steam) + 7½ volumes N.

In practice. the exact composition of the after-damp will depend upon the composition of the explosive mixture. In every case the whole of the marsh-gas will be broken up and—if there be insufficient oxygen to consume all the marsh-gas and coal-dust, if the last be present—some carbonic oxide and hydrogen will be formed. In all probability, carbonic oxide is formed in the majority of explosions in mines. (Thomas's "Coal-Mine Gases, and Ventilation," p. 323.)

The force developed by an explosion of marsh-gas and air depends upon a multitude of circumstances, many of which cannot be determined in the case of an explosion in a mine. But in the case of a mixture of marsh-gas and air in the most explosive proportions, and enclosed in a strong vessel, we can calculate the force developed, as follows:

1 lb. of CH_4 burning to CO_2 and H_2O yields about 23·550 units of heat. (See p. 34.)

Let the initial temperature be 62° Fahr. = 521° absolute.

$$1\text{ lb. } CH_4 = 12\text{ oz. C} + 4\text{ oz. H},$$
$$12\text{ oz. C} + 32\text{ oz. O} = 2{\cdot}75\text{ lbs. } CO_2.$$
$$4\text{ oz. H} + 32\text{ oz. O} = 2{\cdot}25\text{ lbs. } H_2O.$$

And 64 oz. O are contained in about 17 lbs. air.

We have then, taking specific heat at constant volume,

CO_2	$2{\cdot}75 \times {\cdot}1711 = {\cdot}470$	units of heat to raise	2·75 lbs. CO_2 one deg.
H_2O	$2{\cdot}25 \times {\cdot}364 = {\cdot}819$	do.	2·25 lbs. H_2O one deg.
N	$13{\cdot}00 \times {\cdot}1727 = 2{\cdot}245$	do.	13·00 lbs. N one deg.
	18·00 3·534		18·00

Then the degrees the mixture will be raised are $\frac{23550}{3{\cdot}534} = 6663°$ Fahr., and the volume it will seek to attain $= \frac{521 + 6663}{521} = 13{\cdot}8$, *i. e.*, the steady pressure due to the explosion = 13·8 atmospheres; but to this must be added a considerably increased force due to shock, the amount of which cannot be calculated. When it is remembered that 13·8 atmospheres are equal to 30,000 lbs. per sq. ft., whereas the force of a hurricane moving at the rate of 100 miles an hour is only 50 lbs. per sq. ft., some idea of the terrific force of an explosion may be realized.

At the Haswell Explosion, in 1844, Faraday and Lyell drew attention to the part that coal-dust might play in an explosion; but, though the question has cropped up from time to time since, it is only recently that the matter has been thoroughly investigated. Mr. Galloway has within the last few years proved that an explosion may be caused with coal-dust and air, without the presence of any gas. (See Trans. Royal Soc. 1876—1884, and "Nature," 6th Nov., 1884.) And it is now admitted that many of the most violent explosions of recent years were due in part, if not entirely, to coal-dust. (See "Explosions in Coal-Mines," by Atkinson.)

The *detection of fire-damp* is usually effected with the Davy lamp: but, since it has been shown by Sir Frederick Abel that, if coal-dust be present, 1·5% of gas in the air will render the mixture explosive, a more delicate test is required. The following detectors are described in the Trans. N. E. I., viz.: Ansell's, vol. xv.; Steavenson's, vol. xxvi.; Liveing's, vol. xxvii.; Forbes', vol. xxix.; and Maurice's, vol. xxxvi. Chatellier has introduced a lamp with screen and two shields for the same purpose.

METHODS OF DEALING WITH FIRE-DAMP.

Removal by Firing. Now no longer practiced. Drainage of goaves by pipes to the upcast (See Faraday and Lyell's report on the Haswell Explosion), or by bore-holes to the surface; both impracticable. Drainage of whole coal by bore-holes and gas-drifts in a higher seam might answer in certain cases.

Dilution with Air.

Absence of Heat. Heat is required for light and for shot-firing. The steel mill of Spedding about 1740. Reflected light, and fish-skins have been tried.

The safety-lamp, due to Clanny, 1811; Davy and Stephenson, 1815. The safety of the lamp depends upon the fact that metal gauze permits air and light to pass, but not flame. The conducting power of the gauze is impaired by over-heating, broken wires, dirt, or exposure to a current of gas.

The maximum of safety, combined with the maximum of light, is obtained from gauze with wires $\frac{1}{80}$ to $\frac{1}{40}$ in. dia., and spaced with 28 apertures to the linear inch.

AIR.

1,000 cubic feet of air at temp. 32° Fahr. and 30 in. bar. weigh 80·9 lbs.

Air is a mixture of oxygen and nitrogen, with traces of some other gases, and vapor of water. Its composition varies a little in different places.

100 cubic feet of pure dry air contain:

Oxygen	20·99 cu. ft.
Nitrogen	78·98 ,,
Carbonic Acid Gas	0·03 ,,
	100·00 cu. ft.

(*Angus Smith.*)

100 cubic feet of ordinary air contain;

Oxygen	20·61 cu. ft.
Nitrogen	77·95 ,,
Carbonic Acid	0·04 ,,
Vapor of Water	1·40 ,,
	100·00 cu. ft.

Air is purified by diffusion, the wind, rain, plants, and animals. It is vitiated by withdrawal of oxygen, as in the breathing of men and horses; the combustion of lamps, candles, and gunpowder; the conversion of iron pyrites into sulphate of iron, $2FeS_2 + 4O_2 = 2FeSO_4 + S_2$; the oxidation of small coal; &c., &c. And vitiation by the introduction of foreign substances, such as the occluded gases, the products of combustion and respiration, vapor of water and coal-dust.

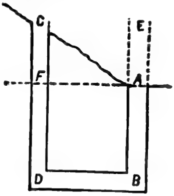
Angus Smith considers that two miners, using ½ lb. candle and 12 oz. of powder, will produce 25½ cu. ft. of CO_2 in 8 hours. Thomas, quoting Boussingault, says that a horse will produce 155 cu. ft. of CO_2 in 24 hours. But the quantity, both in men and horses, is very variable, and, as certain organic exhalations are also given off in breathing, which, though they may not be capable of detection by chemical analysis, are more deleterious than CO_2, no estimate of the volume of air required can be formed from an attempt to calculate the CO_2 produced.

The quantity of air required depends upon the conditions of each mine. In the North of England, the volume seems to vary from 100 to 500 cubic feet per minute per person employed, and from 30 to 160 cubic feet per min. per ton of coal worked per day. The velocity in the workings should be about four feet per second.

NATURAL VENTILATION.

In order to understand the theory of natural ventilation, it must be remembered that the height of the atmosphere does not follow the undulations of the earth's surface, but that its outer edge is everywhere equi-distant from the earth's center, and that if it is 50 miles high from the bottom of a valley it will only be 47 miles high from the summit of a neighboring mountain which is 3 miles high; from which it follows that the pressure at the summit of the mountain is always less than it is at the bottom of the valley. Hence, if two shafts are sunk from different surface levels to the same level of a seam and are connected by an air-way, and there is a difference in the temperature of the air inside and outside of the mine, there will be a current of air created, because the density of the columns of air in the two shafts will differ.

To illustrate this, let A B be a shaft 100 feet deep and C D another shaft 200 feet deep, connected at the bottom by the heading B D. Suppose the air inside to be the warmest, as in winter, and for example let the air inside weigh one-half ounce per foot of shaft per square yard of section, and the outside air weigh three-fourths of an ounce for the same bulk; then the relation between the two shafts would stand thus:



Shallow shaft, 100 feet at ½ ounce per foot........	50 oz.
Outside column from A to E at ¾ ounce per foot and 100 feet equal	75 oz.
Total	125 oz.
Deep shaft, 200 feet at ½ ounce per foot............	100 "
Difference	25 oz.

The balance in favor of the shallow shaft, 25 ounces, will make the shallow shaft the downcast by a pressure equal to 25 ounces per square yard of section. If the temperature outside were the highest, as in summer, this result would be reversed. The difference of weight between the air in the deeper shaft from F to C and the imaginary column A E is the pressure producing ventilation.

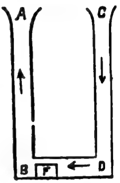
In the case of a drift driven into the side of a hill with an air-shaft opened to its summit under similar conditions, the same results are produced. The difference in the weight of the air in the shaft and of an imaginary column in the open air, from the mouth of the drift to the level of the top of the shaft, is the pressure producing ventilation. In winter, when the temperature inside the drift is warmer than the air outside, the current will be up the shaft, but in summer, when the outer air is the warmer, the current will be reversed, and the direction will be out the drift. When the temperatures inside and outside are equal there will be no current. Natural ventilation, on account of its feebleness and liability to derangement by change in the temperature of the atmosphere at the surface, is inadequate for operations of considerable extent, and recourse must be had to artificial ventilation.

FURNACE VENTILATION.

The object of a ventilating furnace is to strengthen the natural current, which it does by imparting additional heat to the upcast column, and so reducing its density. When air is heated by contact with the fire, it is lightened and is no longer able to resist the pressure of the colder air behind it. The higher the temperature is raised, the greater the velocity of the current, and the larger the quantity of air obtained.

The air after passing the furnace is enlarged in volume, and, therefore, the upcast shaft should be larger than the downcast, to keep down the velocity of the current. It should also be lined and dry, so as to hold the heat. If the upcast is cold and wet, the larger it is the greater will be its cooling-surface, and under such circumstances the upcast shaft should not be too large. If the return current of a mine is loaded with fire-damp, or black-damp, it should not be passed through the furnace, as the one may explode and the other partially extinguish the fire. In such cases, the current is carried over the furnace to the heated upcast in a "dumb drift," which enters the upcast shaft about 50 feet above the furnace; the furnace being fed by a separate split from the surface. The furnace should be located about 50 yards from the upcast shaft, and the furnace drift should rise 1 in 6 from the furnace to the shaft. In practice the amount of air passing varies from 4,000 to 8,000 cubic feet per minute for every foot breadth of bars.

All other things being equal, the amount of air obtained varies as the square root of the depth of the shaft.



To illustrate one of the methods of ascertaining the amount of ventilation obtained with a furnace, in the following diagram let AB and CD be two shafts, each 459 feet deep and 10 ft. by 10 ft. connected by the airway DB, of the same size and length as either of the shafts. Let F represent location of the furnace.

Let the temperature of the downcast and air-way be 50°, and the average temperature of the upcast be 100°, then the furnace will have raised the upcast temperature 50°, and as the shaft is 459 feet deep and 459 feet of air expand one foot for every degree of heat added to it, it follows that the furnace, having added 50°, will have expanded the upcast column of air 50 feet, or, to put it more plainly, the furnace has forced a quantity of air out at the top of the upcast equal to what would fill 50 feet of the shaft at a temperature of 100°.

To find the weight of this column of 50 feet, first find the weight of one foot of air at 100°, and as this varies with the pressure, as shown by a barometer, suppose the pressure equal to 30 inches of mercury; then find the weight by the formula.

$$\frac{1{\cdot}32529 \times 30\,\mathrm{B}}{459 + 100^\circ} = {\cdot}0711246 \text{ lbs.} = \text{weight of one foot.}$$

As ·0711246 lbs. is the weight of one foot at 100°, 50 times that amount will be the weight of the column.

$$\begin{array}{r} {\cdot}0711246 \\ 50 \\ \hline 3{\cdot}5562300 \end{array} = \text{weight of 50-foot column.}$$

Therefore a pressure of a little over three and one-half pounds per square foot is producing the ventilating current under these conditions.

Having found the pressure, now find the rubbing-surface presented to the air, in both shafts and airway, so as to get at the resistance which the pressure has to overcome. Each shaft 10 feet by 10 feet = 100 feet area, and the four sides, 10 feet each, makes 40 feet around each shaft and airway. This is the perimeter, which, multiplied with the length, gives the rubbing-surface:

Depth,	459 feet.
Perimeter,	40
Rubbing-surface,	18,360

square feet in each, and, as all three are one size, three times this quantity is the whole rubbing-surface:

$$\begin{array}{r} 18{,}360 \\ 3 \\ \hline 55{,}080 \end{array} \text{ feet} = \text{total rubbing-surface.}$$

The next factor required is the co-efficient of friction; that is, the pressure required to overcome the resistance of the air in rubbing against the surface of the passages of a mine exposed to the current. This is got by experiment, and has been found to vary with the character of the surfaces exposed to the

current. Most authorities use the co-efficient ·0000000217 pounds pressure per square foot of area of air passage for every square foot of rubbing-surface exposed to the current moving at the rate of one lineal foot per minute.

If the pressure per square foot is multiplied by the area, the product will be the total pressure, = 355·623 pounds, and, if the rubbing surface is multiplied by the co-efficient of friction, the product will be the pressure required to overcome the friction at a velocity of one foot per minute = ·0011952360 pounds. As the resistance is in proportion to the square of the velocity, if the whole pressure is divided by the pressure necessary to overcome the friction at a velocity of one foot per minute, the result will be the square of the velocity, the square root of which is the velocity itself.

$$\frac{355·623}{·0011952360} = 297,533$$

and $\sqrt{297,533} = 545$ feet, the velocity per minute. The velocity multiplied by the area of the air-way gives the quantity passing.

$$\begin{array}{r} \text{Velocity } 545 \\ 100 \\ \hline 54,500 \text{ cubic feet.} \end{array}$$

This is the work of a furnace under these conditions against friction. If there was no friction to be taken into consideration, the result would be much greater.

The power obtained by furnace ventilation is measured by the difference between the weight of the air in the downcast and upcast shafts. The length of the column in the downcast shaft, which would be equal in weight, to the difference of the weight of the air in the two shafts, is called the *motive column*.

The motive-column is usually found by the formula:

Let M = motive-column
T = temperature of upcast
t = temperature of downcast
D = depth of downcast;

$$\text{and then } M = D\frac{T - t}{T + 459}$$

In the present case it may be found by dividing the pressure per squar. foot, 3·55623 pounds, by the weight of one foot of the downcast air-column which, found by the formula already given, is ·0781113 pounds. The pressure per square foot divided by this = 45·52 feet, the length of the motive-column.

Under these circumstances, then, the air in the downcast would balance that of the upcast with a column 45·52 feet shorter than that in the upcast. This may be taken to be a vacuum. The theoretical velocity of air in rushing into a vacuum is the same as the velocity that a falling body would attain at a depth represented by the length of the vacuum, or the velocity is 8 times the square root. In this case it would be $8 \times \sqrt{45·52} = \sqrt{45·52} \times 8 = 53·968$ ft. per second, or $53·968 \times 60 = 3,238·08$ feet per minute, or $3,238·08 \times 100 = 323,808$ cubic feet for the whole air-way. The actual current secured, therefore, is much smaller than the theoretical result, owing to the resistances the air meets with in its passage; the amount of ventilation obtained from the motive column depending on the length and sectional areas of the air-ways.

FRICTION OF AIR IN MINES.

Friction is produced by something rubbing against something else, and friction in ventilation is the result of the air-current rubbing against the surface of the passages through which it is moving.

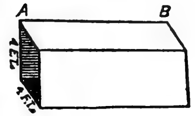


FIG. 1.

When the barometer reads 30 inches the pressure on all surfaces exposed to the air is 2120·25 pounds per square foot. In figure 1, let AB represent an air-way, 4 feet wide, 4 feet high, and 1,500 feet in length. The amount of surface in this air-way against which the air presses as it moves along is 4 + 4 + 4 + 4 = 16 feet for each foot of its length, and as it is 1,500 feet long—the total amount of pressing surface will be 16 times 1,500 or 24,000 square feet. As the pressure per square foot, as before stated, is 2120·25 pounds, the total pressure on this air-way will be 24,000 times 2120·25 or 5,128,600,000 pounds, or 25,443 tons.

If an air-way only 4 feet high, 4 feet wide, and 1,500 feet long bears a pressure of 25,443 tons, it is not difficult to see where friction comes from.

Friction is the result of the air which exerts the great pressure just shown,

rubbing against the surfaces of the air-ways, and it necessarily follows that it will increase or decrease as the surface of the air-ways is increased or decreased, providing the velocity at which the air is passing remains the same—that is, the friction is doubled when the surface of the air-ways is doubled, and it follows also that if the rubbing surface is doubled, the friction doubled, and the distance that the air must pass over doubled, the total pressure putting the air in motion must also be doubled to produce the same velocity of the air-column and to furnish the same quantity of air. Hence, if a given pressure is moving air in an air-way 500 yards long, and the air-way is extended to 1,000 yards in length, the resisting surface will be doubled, the length the air has to pass will be doubled, and the pressure will also have to be doubled to maintain the same velocity and quantity.

This leads to the consideration of another condition as regards the extent of the resisting surface. In ventilation, pressure is measured by an instrument known as the water-gauge, which is a measure of the difference of the density of the intake and return air, and consequently is a measure of the amount of pressure putting the air in circulation; that is, when an exhausting machine is used, it is a measure of how much less pressure is on the outlet than on the inlet, and when a forcing-machine is used, of how much more pressure there is on the inlet than on the outlet In speaking of pressure the terms are used which express its force on every square foot of the area of the air-way.

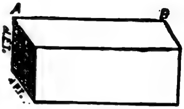


FIG. 2.

In case of two air-ways of unequal area but of equal rubbing surface—the smaller one can be so much longer as to make up the difference—with the same total pressure the velocity will be the same, as both present the same resistance, but the total pressure spread over the larger one will be less per square foot than on the small one, and the quantity or volume of air obtained will be in proportion to their areas. This principle may be illustrated by figures 2 and 3. In figure 2, let A B be an air-way 4 feet high and 4 feet wide, and 1,000 yards long; then the sum of its four sides is 16 feet, and it will have 16 square feet of rubbing surface for every foot of its length, or 48,000 square feet.

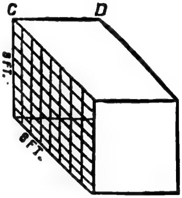


FIG. 3.

In figure 3 let the air-way C D be 8 feet high, 8 feet wide, and 500 yards long; then the sum of its four sides will be 32 and it will have 32 square feet of rubbing surface for every foot of its length, or 48,000 square feet.

It is thus seen that the friction in both these air-ways is alike because their surfaces are equal, and to move air in either at the same speed will require the same total pressure because the resistance is the same.

If they are subjected to the same total pressure, and the pressure upon the large one, the area of which is 64 square feet, is 1 pound per square foot, then the pressure upon the small one, the area of which is but one-fourth as much as that of the larger or 16 square feet, will be 4 pounds per square foot.

Then, as the velocity is the same in both air-ways with the same total pressure, while the small air-way is passing ten thousand cubic feet, the large one will pass forty thousand cubic feet. Hence, the large air-way will give four times as much ventilation as the small one, with one-fourth the pressure per square foot, or one fourth the water-gauge, although the total pressure is equal for both.

If the large air-way is made as long as the small one, to continue to obtain four times as much air, will require one half the pressure per square foot, that is on the small air-way or twice the total pressure. This is a forcible illustration of the great superiority of large air-ways over smaller ones.

The next law to consider is that governing friction at different velocities. If the pressure is increased, the speed of the air-column and quantity of air obtained will also be increased, but not in the same proportion. Four times the pressure will produce double the quantity; nine times will produce three times the quantity, and sixteen times the pressure will give four times the quantity of air, and in that proportion. *The quantity of air obtained will vary as the square foot of the pressure applied*—the pressure per square foot of the area—and the pressure will vary as the square of the velocity of the air-column or quantity obtained. If the pressure is re-

duced to one-quarter (¼), the quantity obtained will be one-half (½) or the square root of (¼), and if the pressure is reduced to one-ninth (⅑), the quantity obtained will be one-third (⅓), and in that proportion.

It will assist to understand the principle that the pressure required to move air varies as the square of the velocity of the air-current or the quantity obtained, to imagine an air-way with something that can be seen moving through it. Air is invisible, and it is difficult to grasp a conception of its motions. In figure 4, let A B be an air-way four feet high, four feet wide, and, therefore, of sixteen square feet area, and eight hundred feet long, divided for illustration into eight divisions of one hundred feet each, with a column of steam moving through it at a velocity of one hundred feet per minute. Suppose the pressure putting the column of steam through the air-way be two pounds to the square foot. Imagine the column of steam to be divided into blocks of 1 cubic foot each. It will be noticed that these blocks (sixteen in number), as represented in the mouth of the air-way, in moving through it, rub against its sides as follows:

Block	1	has	2 sides	rubbing.
"	2	"	1 side	"
"	3	"	1 side	"
"	4	"	2 sides	"
"	8	"	1 side	"
"	12	"	1 side	"
"	16	"	2 sides	"
"	15	"	1 side	"
"	14	"	1 side	"
"	13	"	2 sides	"
"	9	"	1 side	"
"	5	"	1 side	"
	Total		16 sides	"

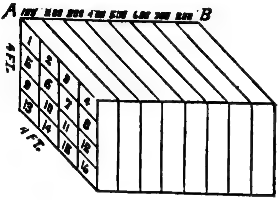


FIG. 4.

or 16 square feet. Blocks 6, 7, 10, and 11 have no sides rubbing, and, therefore, create no friction. These blocks, which move at a velocity of 100 feet per minute, will every minute move the length of one division of the air-way and rub against 100 feet lineal, or 1,600 square feet of rubbing surface, and in eight minutes will move the full length and rub against 800 feet lineal or 24,000 square feet, the aggregate rubbing surface. Suppose three times the quantity of steam is required. This will necessitate moving the column three times as fast. If the blocks, then, at a velocity of 100 feet per minute, moved through one division of the air-way and rubbed against 100 feet lineal, or 1,600 square feet of rubbing surface, at a velocity of 300 feet per minute, they will move through three divisions of the air-way and rub against 300 feet lineal, or 4,800 square feet of rubbing surface. They will thus meet with three times the rubbing surface or friction in a minute, and if the pressure per square foot was originally 2 pounds, it will have to be increased three times and raised to 6 pounds per square foot, 2 pounds $\times$ 3 = 6 pounds. But there is another force that must be taken into consideration. The blocks, instead of striking against the rubbing surface with a momentum gained from a velocity of 100 feet per minute, as in the first instance, strike against it with a momentum gained from a velocity of 300 feet per minute. Thus, each block will also create a resistance, from the greater momentum acquired, three times greater than before, and thus require the pressure to be again increased three times, and raised from 6 lbs. per square foot to 18 lbs.; 6 lbs. $\times$ 3 = 18 lbs., or 9 times the original pressure of 2 lbs.

2	2	2	2
2	2	2	2
2	2	2	2
2	2	2	2

FIG. 5.

6	6	6	6
6	6	6	6
6	6	6	6
6	6	6	6

FIG. 6.

18	18	18	18
18	18	18	18
18	18	18	18
18	18	18	18

FIG. 7.

From figures 5, 6, and 7 a proper conception of the relative pressures upon the area of the air-way, made necessary by the greater friction developed by the changed conditions, may be obtained

Figure 5 represents the area of the air-way with a pressure of 2 lbs., per square foot or a total pressure of 2 lbs, $\times$ 16 = 32 lbs.

Figure 6 represents the area of the air-way, with the pressure per foot increased three times to overcome the friction developed in the triple rubbing surface passed over in the same time—one minute—which is 6 lbs. per square foot, or a total pressure of 6 lbs. $\times$ 16 = 96 lbs.

Figure 7 represents the area of the airway, with the pressure increased three times to overcome the resistance due to the triple amount of rubbing-surface passed over in the same time, and again increased three times to overcome the friction developed by the blocks striking the rubbing surface with three times the momentum attained from three times the velocity, or 3 $\times$ 3 = 9 times 2 lbs. = 18 lbs., making a total pressure of 18 lbs. $\times$ 16 = 288 lbs. *Nine is the square of three, and the pressure, therefore, varies as the square of the velocity or quantity obtained.*

Another and perhaps the most important principle involved in the friction of air in mines, is the relation between the power expended and the result obtained, or the units of work given out and the velocity or quantity of air produced. How the pressure applied to each square foot of the area is affected by changes in the velocity has been explained. It remains to explain how the power of units of work given out are affected by the velocity. It has been shown that the result or quantity obtained is in proportion to the square root of the pressure, and that the resistance or friction developed is in accordance with the square of the velocity or quantity obtained, as is also, as a matter of course, the pressure necessary to overcome it.

The velocity or amount of air obtained is in proportion to the cube root of the power expended, and the power necessary is in proportion to the cube of the velocity or quantity of air obtained. It may seem strange, if a fan driven by an engine of ten horse-power produces 10,000 cubic feet of air per minute, and it is desired to increase the quantity of air to 40,000 cubic feet per minute, that it will be necessary to obtain an engine of 640 horse-power or 64 times larger, but it is nevertheless true.

Before this law can be understood a proper appreciation of what is meant by the term power must be had. It is of the greatest importance that the difference in the meaning between the terms "pressure" and "power," as used in ventilation, be borne in mind. Pressure is the force on each square foot of the area of the air-way, which is overcoming the resistance, while power is this force multiplied by the amount of displacement it is producing or the result it is accomplishing in a given time. As explained in "Mechanics," work is the product of the force multiplied by the displacement it produces in its point of application. In this definition the force is supposed to be constant, and the point of its application to coincide with the direction of the force. In expressing the work done with a force, the units of weight lifted through a unit of height, as in pounds lifted one foot, called foot-pounds are employed. The rate of working of a machine or the "power" it develops is expressed by the units of work done in a unit of time, as in foot-pounds per minute, or in conventional units called horse-powers. One horse-power is equivalent to 33,000 foot-pounds per minute, or 33,000 pounds lifted one foot high in one minute. Thus a machine that can raise 12 tons through a height of 10 feet in two minutes is rather more than 4 horse powers. This may be proved as follows: 12 tons reduced to pounds is 26,880 pounds, which multiplied by 10 feet gives 268,800 pounds lifted through one foot, or foot-pounds, and divided by 2 gives 134,400 pounds lifted through one foot in one minute, and this divided by 33,000, the number of foot-pounds in a horse-power, gives 4·07 horse-powers.

To find the power exerted by a steam-engine, the load or total pressure on the piston is multiplied by the number of feet the piston travels with the load. The result thus obtained represents the units of work or foot-pounds, and divided by 33,000 gives the number of horse-powers. On the same principle, when it is desired to find the horse-powers exerted by a fan in moving a current of air, the pressure per square foot, as represented by the difference of water level in the two columns of the water gauge reduced to pounds, is multiplied by the number of cubic feet passing per minute. This result is the units of work or foot-pounds, and divided by 33,000 gives the horse-powers exerted by the fan.

The water gauge reading simply gives the pressure expended on each square foot of the area of the air-way, and therefore the reason why the product of these two factors is the units of work requires explanation. The second factor or the quantity of air passing is found by multiplying the total area of the air-way by the velocity or the quantity passing per foot per minute. Then in the multiplication of the two factors—the water gauge reading and the quantity passing per minute—the pressure per square foot multiplied

by the number of square feet in the area of the air-way, then by the velocity or the length of the air-column passing in a minute. This is the same as if the total pressure had first been found by multiplying the water gauge reading, reduced to pounds by the area of the airway, and then multiplying the result by the velocity or the length of column passing in a minute. The total pressure exerted by the fan would then represent, in the case of an engine, the load on the piston, and the length of the air-column passed per minute or the velocity would represent the distance or piston speed. This may be further illustrated by an example: An air-way 2 feet high by 2 feet wide is passing 4000 cubic feet of air per minute with a pressure of 1 pound; then the units of work are by the rule:

$$\begin{array}{r} 1 \\ 4{,}000 \\ \hline 4{,}000 \end{array}$$

foot pounds per minute. But the area of the airway is

$$\begin{array}{l} 2 \text{ ft.} \\ 2 \text{ ft.} \\ \hline 4 \text{ square feet} = \text{area.} \end{array}$$

And as the pressure is 1 pound, the total pressure will be 4 pounds, and the quantity passing per minute (4000 cubic feet) divided by the total pressure, 4 pounds, will give 1,000, the velocity or length of column passing in a minute. Then:

$$\begin{array}{ll} 1 \text{ lb.} & = \text{Pressure} \\ 4 & = \text{Area} \\ \hline 4 & = \text{Total pressure} \\ 1{,}000 & = \text{Velocity} \\ \hline 4{,}000 & = \text{foot-pounds per minute} \end{array}$$

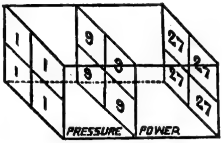


FIG. 8.

or the same result. The total pressure represents the weight to be lifted and the velocity or length of column passing in a minute, the height it is lifted through in a minute, and their product is converted into horse-powers by dividing it by 33,000. Hence, a fan that is working with one inch of water gauge and discharging 33,000 cubic feet of air per minute is exerting a little more than five theoretical horse-powers to overcome the resistance of the air at that speed, and if to do this work an engine of 10 horse-power is required, we know that 50% is wasted, in friction in the machinery and in transmission between the boilers and the result.

This is what is meant by power in ventilation, and that the power required varies as the cube of the velocity or quantity passing, and the velocity or quantity passing as the cube root of the power is demonstrated as follows: Let figure 8. represent an air-way of four square feet area, with a pressure of 1 pound per square foot, and 4 pounds total pressure, giving 1000 cubic feet of air per minute. The unit of work found by multiplying the pressure by the quantity passing will be

$$\begin{array}{l} 1 \\ 1000 \\ \hline 1000 = \text{foot pounds.} \end{array}$$

To put three (3) times the quantity through or 3000 cubic feet per minute, will require three (3) times the velocity. But it has been shown that three (3) times the velocity will develop nine (9) times the resistance and require nine (9) times the pressure, or the square of the increased velocity, which is nine (9), times the pressure, or the square of the increased velocity, which is nine (9), to overcome it. Hence, it follows that if the velocity is trebled that each pound of pressure in the air-way will have to be increased to nine (9), making a total pressure of 36 pounds. Now as the power exerted is found by multiplying the pressure by the velocity, this nine (9) times the pressure required to overcome the resistance must also be multiplied by three (3), the ratio of increase of speed. As the new pressure required is nine (9), or the

square of the increased velocity, the new power required will be 27, or the cube of the new velocity.

$$\begin{array}{l} 3 = \text{new velocity.} \\ \underline{3} \\ 9 = \text{square of velocity} = \text{new pressure.} \\ \underline{3} \\ 27 = \text{cube of velocity} = \text{new power.} \end{array}$$

In the first instance the units of work were the pressure, 1 pound, multiplied by the quantity 1000 cubic feet, making 1000 foot-pounds per minute. Now the units of work are the pressure, 9 pounds, multiplied by the quantity, 3000 cubic feet, making 27,000 foot pounds per minute; so that the increased velocity has been cubed, giving 27 times the original power or foot-pounds per minute. And if the power increases as the cube of the velocity, as a matter of course, the velocity or quantity of air obtained by different powers will vary according to their cube roots. Therefore, in case a furnace is used in ventilating, it will require eight (8) times the coal to double the quantity of air, twenty-seven (27) times to treble it, sixty-four (64) times to quadruple it, and so on in that proportion, and if a fan is used, the increase of coal necessary to raise steam will be in the same ratio, as the same law controls in both cases. The law seems complicated, but it is only the simple law of mechanics by which the power of a steam engine is found, viz: the load or resistance multiplied by the volume passing or distance traveled in a minute or any unit of time.

Mr. J. J. Atkinson, in his admirable work on "Friction of Air in Mines," says with regard to the co-efficient of friction that "for a velocity in the air of 1000 feet per minute, the friction is equal to 0·26881 feet of air-column of the same density as the flowing air, which is equal to a pressure, with air at 32°, of 0·0217 pounds per square foot of area of section. Calling this the co-efficient of friction, we have the following rules with respect to the friction of air in mines:

$$\text{Total pressure, } p\,a = k\,s\,v^2. \quad \text{Rubbing surface, } s = \frac{p\,a}{k\,v^2}$$

$$\text{Square of velocity, } v^2 = \frac{p\,a}{k\,s}$$

$$\text{Co-efficient of friction, } k = \frac{p\,a}{s\,v^2}$$

$$\text{Pressure per foot, } p = \frac{k\,s\,v^2}{a}.$$

$$\text{Area of section, } a = \frac{k\,s\,v^2}{p}$$

Where p = pressure per square foot; a = sectional area in feet; s = the area of rubbing-surface exposed to the air; v = the velocity of the air in thousands of feet per minute, 1000 feet per minute being taken as the unit of velocity; k, the co-efficient of friction in the same terms or unit as p is taken.

The co-efficient varies with the nature of the rubbing-surface, and consequently may be different in the different air-passages of the same mine. The following plan may be adopted for ascertaining the friction of air in a passage: Place a gutta-percha tube of small section along the portion of the gallery, the friction of which it is desired to know; close the end of the tube fixed opposite to the current, and place a water-gauge on the closure, and the instrument will then show the difference of pressure at the two extremities of the tube. Then the water-gauge multiplied by 5·2 = p in pounds.

SPLITTING THE CURRENT.

By splitting the air-current, the ventilating-power is economized and greater safety in the mines secured. The former will appear from what has already been said with regard to friction of air in mines. Greater safety is secured because a larger amount of ventilation is obtained with the same power, and also because the fire-damp given off from one set of workings is not passed through the others, but directly to the returns, thereby diminishing the liability of its ignition; and even should an explosion occur its

effects are confined chiefly to the workings ventilated by the split in question. A minor advantage is that the velocity of the air-current can be made much less, and there is less liability of the flame being forced through the gauze of the safety-lamp, which happens with a velocity over 6 feet per second. Of course, the speed of the current in the main intake and returns should not be limited by the above; there will be little liability of the presence of an explosive mixture in the intake, and special rules and precautions can be taken at all times with reference to traveling in and the use of lights in the returns.

The sub-division of the air-current may be carried too far, for should the current be too weak it will fail to cause the rapid mechanical mixture of the light carburetted hydrogen with the current, which is necessary to prevent a lodgment of gas in the higher parts of the workings, since diffusion acts too slowly to be of practical use. Since the air-currents will pass through the various splits in such a manner that the total resistance met with is a minimum, the division should be so effected that the amount passing through each split, and the resistance met with in each split, are the same. Although this result can only be attained in an approximate manner, still a great economy will be attained if this aim is kept in view in laying out the various workings, or rather in dividing the current among the workings.

ASCENSIONAL VENTILATION.

By ascensional ventilation is meant the taking of the intake current at once to the lowest level in the mine, and thence leading it through the workings, always in an ascending direction. This principle is only applicable where the seams have a considerable inclination. It is based upon two considerations. *First*—The intake current is supposed to be always cooler than the return; its temperature is gradually raised as it passes through the workings. The air-current has, therefore, a natural tendency to ascend whilst passing through the workings, and by making the direction of the current to coincide with this natural tendency the current is materially assisted by the latter, whilst in the reverse direction it would be opposed by it. *Second*—In mines containing fire-damp, this being lighter than the air, it will tend to rise, and if the direction of the air-current is ascensional, this tendency will help the air-current to remove it; whilst, on the other hand, if the direction of the current be downward, the natural tendency of the air to rise will oppose its removal by the air-current.

In highly inclined seams, where there are numerous connections between the levels, this principle must be carefully observed, or there will be a grea loss of air. Exhaustive experiments have been made in Belgium to ascertain the advantage of ascensional ventilation, and it has been demonstrated that the loss of air, where attention is not paid to it, is from 33 to 50 per cent.

MEASUREMENT OF VENTILATION.

Three methods have been employed for the purpose of ascertaining the velocities of the currents and the quantities of air circulating in mines.

1. *Traveling at the same velocity as the current and noting the distance passed over in a unit of time.*—This was a very primitive mode, but no doubt when used it gave a fair approximation to the truth; for recent experiments have proved that it admitted of great accuracy for velocities up to 400 feet per minute. It was open to many objections, and would be utterly unsuited to the large mines now existing, since it would be impossible to walk as quickly as the currents travel in the principal splits, and running is not a sufficiently steady pace for the purpose. The process was as follows: Choice was made of a part of the gallery forming the air-way, having as uniform sectional dimensions as could be found, and, after measuring off a distance of a hundred or a hundred and fifty yards in length, the operator took a lighted candle, and walked in the direction of the current, fully exposing the flame to its influence, but taking care to move at such a rate that the flame would burn in an upright position without being deflected from the vertical either by the current or by the progress of the person carrying it. The time required to traverse the distance measured off being carefully noted by a seconds watch, the average rate of walking was thereby determined, and three or four trials served to give the assumed velocity of the air-current. This, multiplied by the average sectional area of the part of the air-way selected for experiment, was taken to represent the quantity of air passing in the unit of time.

2. *Determining from observation the rate at which small floating particles are carried along by the current, and assuming their velocities to be identical with that*

of the air-current itself.—Until recently, observations of the velocity of the smoke from an exploded charge of gunpowder, in a part of the gallery of nearly uniform sectional area, were the means most generally adopted in coal-mines for ascertaining the velocity of air-currents. They are still considerably used, and, so far as regards shaft velocities, they remain the only method. For this purpose an even part of the road should be selected, from 50 to 100 feet in length, and its cubical contents in feet ascertained. Then let off a flash of gunpowder at the windward end of the channel, and observe the number of seconds the smoke is in passing to the other end. Then say, as the time (in seconds) in passing is to the cubic area, so is 60 seconds to the number of cubic feet passing per minute.

EXAMPLE: Length of channel selected, 50 feet; height, 7 feet; width, 7 feet; time in passing, 8 seconds. What is the amount of air?

$50 \times 7 \times 7 = 2450$ cubic feet, area; then as 8 : 2450 :: 60 : 18,375 cubic feet per minute.

Mr. F. G. Clemens, M. E., in a paper read before the May (1881) meeting of the Mining Institute of Pennsylvania, laid down the following rules for the use of gunpowder in ascertaining the velocity of air-currents in mines: *First.*—Always use one cubic inch of gunpowder. *Second.*—The velocity of the current should never be less than 100 feet a minute nor exceed 500 feet a minute. *Third.*—The time should not be less than 12 seconds nor exceed 30 seconds. *Fourth.*—Explode the gunpowder 10 feet to the windward of the first mark. Therefore, in slow currents of from 100 to 250 feet per minute velocity, the distance to be taken over which the smoke passes will be 50 feet; and for the higher velocties of from 250 to 500 feet the distance will be increased to 100 feet.

3. *With the Anemometer.*—This apparatus is of various forms, and may be divided into three classes.

Those having vanes or wands made to *revolve* by the current of air impinging upon them, the rate at which they revolve being indicated by pointers on dials forming a part of the instrument. They include Biram's and others.

Instruments which are affected by the force or impulse of the wind, without being subjected to any continuous revolving motion. These include Dr. Lind's and others.

Those of a more complex character, such as Leslie's.

Biram's anemometer is in general use in this country. Each revolution of the vanes, which is registered on the dial-plate, corresponds to one foot in the linear motion of the air. Then, if the velocity per minute is multiplied by the sectional area of the channel in which the anemometer is placed, the result is the number of cubic feet of air passing per minute.

These instruments do not register the actual velocity of the air, especially in feeble air-currents, but the result is so nearly correct that they answer all purposes. A certain force of air is required to overcome friction and put the instrument in motion. The force varies with each and every instrument Some anemometers will continue to revolve in a current as low as 30 feet a minute; but with the most of them a velocity of 50 feet is required, and 40 feet is recommended as an average allowance to be made to start them. The formula used for true velocities is:

$$V = \cdot 97R + 40.$$

V = True velocity.
R = Recorded revolutions.
40 = Feet allowed to start anemometer.

The following rules are given for every-day use:

First. Use the recorded revolutions of the anemometer as correct; do not bother with any formula.

Second. Measure always at the same time of day, say noon, when the men are at dinner, the cars at rest, the doors most likely shut, and the ventilation moving along its proper channels.

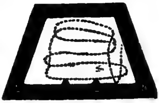
Third. Always use the same places in the air-ways and see that they are as regular and straight as possible.

Fourth. Take the record at several points, say at top, bottom, and center, and the two sides, and use the average of these records for the velocity of the current.

The following rules are used at some of the collieries in the North of England, and are printed in the front of the book, carried by the person whose duty it is to measure the air:

Rule.—Sectional area to be entered at the time of each measurement. Height $\times$ width = area.

The person measuring must hold the anemometer at arm's length in front of his body, and keep the face of the fan square to the current of air, and keep moving it slowly as per the dotted line drawn within the figure below:



The Index figures of the anemometer to be entered continuously.

1. Take the velocity for one minute and make complete entry.
2. Take the velocity for two minutes and divide by two; should the average be near the first reading, enter the average as the velocity.

In all cases add or substract, as the cases requires, the correction due to the instrument.

One page of the book to be used for each measurement. Date and time of day must always be written at the top of the page, and the person measuring must sign his name at the last measurement.

A recent invention is "Davis's Self-Timing Anemometer." It measures the passage of air per second, and is very accurate and convenient. It is essentially a Biram anemometer improved so as to give an accurate reading, and adjusted so no allowance need be made for friction.

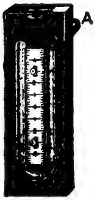
TO FIND THE QUANTITY OF AIR BY THE THERMOMETER.

Temperature of air (t) on the outside of the current being very accurately taken, raise the temperature of the thermometer 10° above t, and then observe the number of seconds (s) which elapse while the thermometer exposed to the free current of air cools to 5° of the 10°, then

$$\frac{c}{s^2} = \text{feet per second velocity,}$$

c being a constant peculiar to the instrument; in one case, for example, it was 16,000. Let the bulb be very clear.

THE WATER-GAUGE.



The water-gauge is used to measure the dynamic force of a current of air. It consists of a U-shaped tube of equal area throughout. The arms are about six inches long, provided with a scale divided into inches and fractional parts of an inch, so that the difference between the height of the water in one arm of the tube, and that of the other may be measured. One arm is placed in connection with the air passing in the mine by placing the tube A through a hole in the brattice or fan casing, while the other is opened to the air-way from the mine. The difference in water-level will indicate the drag, or the resistance to the air in the mine.

The weight of one cubic foot of water at 62° Fahr. and 30 inches barometrical pressure is 62·32102 lbs. The weight of 1 cu. in. is therefore 62·32102÷1728, or 0.036. When the gauge measures one inch, the pressure is $0{\cdot}036 \times 144 = 5{\cdot}184$, or 5·2 lbs. (nearly) to the square foot.

Example.—If a water-gauge read 0·4″, what pressure would it indicate?

$$0{\cdot}036 \times 0{\cdot}4 \times 144 = 2{\cdot}0734 \text{ lbs. per sq. ft.}$$

The water-gauge may be used to show the force of a current produced by a fan or by a furnace, and hence it is very useful as a check to the furnace man. As it tells the amount of resistance to the air in the air-courses, their state or condition may be inferred. If the pressure per sq. ft. exerted by the motive-column be known, the height of a motive-column may be determined by dividing the pressure per square foot by the weight of a cubic foot of air.

Example.—What is the height of the motive-column, if the water-gauge reads 0·4″, the temperature is 62° Fahr. and the barometrical pressure is 30″? The weight of one cubic foot of air at 62° Fahr. and 30″ Bar. is 0·07629 lbs? The pressure is $0{\cdot}036 \times 0{\cdot}4 \times 144 = 2{\cdot}0736$ lbs., and the height of the motive column $= \dfrac{2{\cdot}0736}{0{\cdot}07629}$ or 27·28 feet.

To find the velocity we use the equation for falling bodies, which is

$$8{\cdot}0208 \sqrt{h}$$

This equation is based on the principle that a body falls 16·08, in one second, and that it gains a velocity of 32·16 at the end of the first second. Then the

velocity per second equals 8·0208 times the square root of the height of motive column in feet.

Example.—If the height of the motive-column is 27·28 ft. the velocity per second is $8.02 \times \sqrt{27.28}$ or 41·9 ft.

These formulae may be arranged as follows:

Let P = Pressure in pounds per sq. ft.
Let h = Height of motive-column in feet.
Let V = Velocity in feet per second.

Then:

$$P = 0.036 \times \text{water-gauge} \times 144$$

$$h = \frac{P}{0.0763}$$

$$V = 8.02 \times \sqrt{h}$$

These formalæ, it must be remembered, are only theoretically true, on account of the enormous power required to overcome friction. In practice from 10 to 20 times the theoretical amount of motive-column is required to produce the theoretical velocity. To find the horse-power expended in the power required for a ventilating current, multiply the quantity of air passing by the reading of the water-gauge, and this product by 5·2; divide the result by 33,000.

The quantity of air passing in an air-way is according to the sq. root of the water-gauge.

Thus, if 10,000 cu. ft. is passing per minute with a water-gauge of 1 in., 7,071 cu. ft. is passing with a water-gauge of 0·5 in., or

$$\sqrt{1.0} : \sqrt{0.5} :: 10{,}000 : 7{,}071$$

The following table gives the square root of the water-gauge for each tenth of an inch up to 3 inches.

W. G.	$\sqrt{\text{W. G.}}$	W. G.	$\sqrt{\text{W. G.}}$	W. G.	$\sqrt{\text{W. G.}}$
0·1	0·316	1·1	1·0488	2·1	1·4491
0·2	0·447	1·2	1·0954	2·2	1·4832
0·3	0·548	1·3	1·1401	2·3	1·5165
0·4	0·633	1·4	1·1832	2·4	1·5491
0·5	0·7071	1·5	1·2247	2·5	1·5811
0·6	0·7745	1·6	1·2649	2·6	1·6144
0·7	0·8366	1·7	1·3038	2·7	1·6413
0·8	0·8944	1·8	1·3416	2·8	1·6733
0·9	0·9486	1·9	1·3784	2·9	1·7029
1·0	1·0000	2·0	1·4142	3·0	1·7320

SAFETY-LAMPS.

There are so many modifications of the more successful types of safety-lamps that we only describe the most important. The Royal Commission on Accidents in Mines (British) reports most favorably on the following: Gray's, Marsaut, the Bonneted Mueseler, and Evan Thomas's modification of the bonneted Clanny. There are also several portable electric lamps which give good and perfectly safe light, but they are too heavy and expensive, and they will not indicate the presence of carbonic acid gas.

In commenting on safety-lamps in his "Notes and Formulæ for Mining Students," Mr J. H. Merrivale says:

"In the Author's opinion, too much attention is paid to securing lamps from the action of violent currents to which they are very unlikely ever to be exposed; whilst their illuminating power, a daily necessity, is too much neglected. Inventors appear to forget the importance of a good light all around, including the roof. About 42% of the fatal accidents in mines are due to falls of roof and sides, as against 24% due to explosions, and a very small proportion of these last have been traced to the safety-lamp.

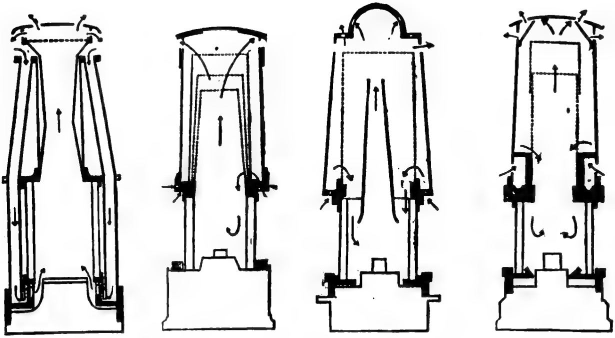
By practical experiments made with various safety-lamps in recent years, the following facts were evolved:

1. If a new gauze be heated quickly to a red heat, it will under certain circumstances give off fumes which will inflame at that temperature. Similar results can be obtained by smearing a gauze with oil.
2. Oil on being poured over red-hot iron will ignite.

These conditions are seldom attained in the actual use of safety-lamps, but it is well to guard against accidents by preventing the cause.

The Davy Lamp.—In 1815 Sir Humphrey Davy invented, and in 1816 constructed the lamp which is known all over the world as the Davy Lamp. He thus describes his invention: The principle of my lamp is, that the flame, by being supplied with only a limited quantity of air, should produce such a quantity of azotic or carbonic acid gas, as to prevent the explosion of the fire-damp; and which, from the nature of its operations, should be rendered unable to communicate any explosion to the outer air. The wire gauze should not be more than 1-20th of an inch square; wire from 1-40th to 1-60th of an inch is the most convenient size, and there should be 28 wires, or 784 apertures per square inch.

The Stephenson or "Geordie" Lamp.—Invented by George Stephenson, Nov. 30th, 1815. He describes his lamp as made to contain burnt air above the flame, and to permit the fire-damp to come in below in small quantity, to be burnt as it comes in, the burnt air preventing the passing of explosion upwards, and the velocity of the current preventing its passing downwards.



GRAY'S MARSAUT. MUESELER. THOMAS'S.

The Clanny Lamp.—The Clanny Lamp was the first alteration in the construction of the Davy Lamp, and it is essentially a Davy Lamp with a glass cylinder replacing part of the gauze, which gives protection to the wick and increases its light-giving properties.

Gray's Lamp.—The Gray Lamp, a sectional view of which is annexed, is a very good lamp. The air enters at the top of the lamp, passes down four tubes, and through a strip of gauze; the products of combustion pass up the cylindrical chimney, in which two truncated cones are inserted to avoid the down currents to which all cylindrical chimneys are liable. This arrangement assures a slow feeding of air to the flame in a current of high velocity.

The Marsaut Lamp.—The Marsaut lamp is a shielded Clanny with three conical shaped gauzes. As will be seen by the sectional view, the air enters through the gauzes above the glass cylinder, and the products of combustion pass out through the top of the gauzes.

The Bonneted Mueseler.—The Bonneted Mueseler shown in section is a modification of the Belgian Mueseler. The modification consists in shortening the chimney so that it does not reach so far down in the lamp, and in the addition of a metallic shield or bonnet. The air enters above the flame and passes through a gauze disc down to it. The products of combustion pass up a conical chimney, and thence out through the top. The inlet and outlet holes are so arranged that the air is fed to the flame at a low velocity.

Evan Thomas' Modification of the Bonneted Clanny.—Inside the bonnet a brass tube, one inch high, fits the main gauze cylinder closely. To the upper end of this tube is attached a horizontal brass flange extending nearly to the bonnet, so that an annular space, only 1/16 of an inch wide, is left between the edge of the flange and the bonnet. The air, having entered the bonnet through horizontal slits near its lower end, passes through this annular space into the gauze cylinder, and descends into the flame. The products of combustion escape through holes near the top of the bonnet which are protected by a shield fixed in the bonnet. The main gauze cylinder is

provided with a gauze cap. The shield inside the bonnet protects the bottom of the gauze cylinder. The bonnet is locked by a sliding bar which cannot be withdrawn until the oil-vessel is removed. In a gas mixture the gas only burns in the gauze cylinder between the top of the brass tube and the lower edge of the gauze cap, consequently a very small area of the gauze is heated, and the temperature is necessarily low. In air moving with any velocity up to 3,500 ft. per minute the flame burns very steadily when the lamp is either erect or inclined. The flame is scacrely affected by violent oscillations of the lamp or by rapid motion up and down in a vertical direction, and it is not extinguished by inclining the lamp until the latter is nearly horizontal.

The three first described are the lamps in general use in American collieries. They have been supplanted in the collieries of Great Britain and the continent of Europe by the more modern lamps, owing to their liability to explode when the gas fires in them, and their inefficiency in strong currents of air.

THE BAROMETER.

Atmospheric Pressure.—The atmosphere surrounding the earth, being a fluid acted on by gravity, presses upon all bodies immersed in it, in accordance with the general laws of fluid pressure.

The pressure of the atmosphere upon any body will consequently vary with the depth of that body below its highest surface. As, however, the dimensions of any ordinary body upon the surface of the earth are inconsiderable, when compared with the height of the atmosphere, this pressure may, without any sensible error, be regarded as the same at all points in any such body.

It is found by experiment that the pressure which the atmosphere exerts upon a body, on or near the surface of the earth is at the rate of about 15 lbs. for every quare inch of surface. That we are not, in ordinary circumstances, cognizant of this pressure arises from the characteristic property of fluids, in accordance with which they press in all directions upon bodies immersed in them; so that if the upper surface of a body, subject to the pressure of the atmosphere, experience a downward pressure of 15 lbs. to every square inch, the under surface experiences a corresponding upward pressure. If, however, we destroy this equilibrium, by removing or diminishing the pressure of the atmosphere upon the side of any body, we are immediately made sensible of the pressure which is exerted upon the opposite side. For instance, if a plate of glass be placed upon the top of a cylindrical receiver connected with an air-pump, and the air be exhausted from the receiver, the plate of glass will be pressed down with a considerable force, and if not strong enough will be broken in pieces.

The atmospheric pressure at the same place is not found to be constant, but undergoes considerable variation. Roughly speaking, it is found to vary between 13¾ lbs. and 15¼ lbs. per square inch. It has been found, however, to be more convenient to measure the atmospheric pressure not by pounds or ounces, but by the length of a column of a fluid, whose weight would be equal to the atmospheric pressure upon its base. Mercury is the fluid most commonly employed for this purpose, and the column of mercury whose weight is equal to the atmospheric pressure is found to vary between 28 and 31 inches.

Mercury is 13·6 times as heavy as water, and therefore the column of water which is equal to the atmospheric pressure will range between 32 ft. and 35 ft.

The average is a little under 30 inches of mercury or 34 ft. of water.

The instruments by which the variation of the atmospheric pressure are observed and mearsured are termed barometers. Barometers are of two kinds, mercurial and aneroid.

The mercurial barometer measures the variation of the atmospheric pressure by the rising or falling of the mercury in a glass tube. This instrument is constructed in the following manner: A glass tube, closed at one end, is filled with mercury, and a finger being placed over the open end, is inverted in an open vessel of mercury. The mercury in the tube will fall till it is balanced by the atmospheric pressure on the mercury in the open vessel. The mercury in the tube will rise as the atmospheric pressure increases, and will fall as it decreases. A graduated scale attached to the tube, by means of which the changes can be observed and measured.

When the mercury falls in the tube it rises in the cistern and consequently the fall of the mercury in the tube, as measured by the scale attached to it, will not correctly measure the variations in the barometrical column, but will be too great by the distance through which the mercury has risen in the

cistern. In like manner when the mercury rises in the tube, the variation as measured by the scale, will be too small by the distance through which the murcury has fallen in the cistern.

If the cistern be large in comparison with the bore of the tube, the variation in the height of the mercury in the cistern is so small that it may be disregarded for ordinary purposes. When greater accuracy is desired, the bottom of the cistern is so made that it can be raised or lowered by a screw, and thereby the surface of the mercury in the cistern can be adjusted to one uniform height.

The Aneroid Barometer.—With the aneroid barometer the pressure of the air is measured without the use of a liquid, as in the mercurial barometer. The pressure of the atmosphere acts upon a circular metal box, which has been nearly exhausted of air, and then soldered air-tight. The sides are corrugated in concentric rings so as to increase their elasticity, and one of them is fixed to the back of the case which contains the whole. The amount of the exhaustion is such that if the sides of the box were allowed to take their natural position, they would be pressed in upon each other, and to prevent this they are kept distended, to a certain extent, by a strong spring, fixed to the case which acts upon the head of a stalk attached to the side next the face. When the pressure of the air increases, there being little or no air inside the box to resist it, the corrugated sides are forced inwards, and when it diminishes again, their elasticity restores them to their former place, and thus the little box becomes a spring extremely sensitive to the varying pressure of the external atmosphere. By an ingenious mechanical arrangement the movement of the sides is transmitted to a needle or pointer on the face, which moving around a dial graduated to represent the inches of the mercurial barometer, enables one to observe and measure the variations of pressure. By means of this mechanism a very small motion of the corrugated sides produces a large deviation of the index hand, in a five-inch barometer, $\frac{1}{250}$ of an inch causing it to turn through 3 inches. Both from its small size and construction, it is extremely portable and consequently a very useful instrument, but from its liability to change from time to time it must be frequently compared with the mercurial barometer.

When the barometer is 27 inches the pressure of the atmosphere per square foot is equal to 1908·23 lbs.; at 28 inches it is 1978·90 lbs.; at 29 inches it is 2049·58 lbs.; at 30 inches it is 2120·25 lbs.; and at 31 inches it is 2190·93 lbs.

To ascertain the amount of pressure per square foot, the table (No. 1) on following page will be useful. Thus, to ascertain the pressure when the barometrical reading is 30 09 in. we add to the 2120·25 lbs., given above as the pressure at 30 in., the amount in the table opposite ·09, or 6·36 lbs. This makes the pressure at 30·09 in. = 2126.61 lbs. If the mercury falls from 30.09 in. to 29·47 in., or ·62 in., the reduction in pressure is 43·82 lbs. per square foot.

Required the amount in cubic feet of air and gas that may be expected to be given off for each 1,000 cubic feet of open space in the goaves or other waste places.

At 30·09 the pressure is..................	2126·61	pounds.
At 29·47 the pressure is..................	2082·80	pounds.
Difference..................	43·81	pounds.

As 2126·61 : 43·81 :: 1,000 : 20·60 cubic feet of gas, which (theoretically) may be expected to be given off by a reduction of pressure equal to that indicated above. A table of pressure is not, however, absolutely necessary for working the proportion.

Height of barometer.	30·09
	29·47
Difference..	·62

As 30·09 : 62 :: 1000 : 20·60 cubic feet.

If we divide the difference by 3, we shall obtain results sufficiently accurate for all practical purposes; thus 62 ÷ 3 = 20⅔ or 20·66 cubic feet. Considerable experience in the use of this instrument in mines has shown that its indications are from one to two, or even three hours behind what is actually taking place; consequently as an instrument for warning the furnace-men to "fire-up" or the engine-tender to urge on the fan, it is worse than useless. It is, however, valuable to superintendents and other officials in the mines as an incentive to thought.

PRESSURE OF AIR, PER SQUARE FOOT, AS SHOWN BY THE BAROMETER AND WATER-GAUGE.

Table No. 1. Barometer.		Table No. 2. Water-Gauge.		Table No. 1. Barometer.		Table No. 2. Water-Gauge.	
In.	Lbs.	In.	Lbs.	In.	Lbs.	In.	Lbs.
1·00	70·68	1·00	5·20	·50	35·34	·50	2·60
·99	69·97	·99	5·14	·49	34·63	·49	2·54
·98	69·27	·98	5·09	·48	33·93	·48	2·49
·97	68·56	·97	5·04	·47	33·22	·47	2·44
·96	67·85	·96	4·99	·46	32·51	·46	2·39
·95	67·15	·95	4·94	·45	31·81	·45	2·34
·94	66·44	·94	4·88	·44	31·10	·44	2·28
·93	65·73	·93	4·83	·43	30·39	·43	2·23
·92	65·03	·92	4·78	·42	29·69	·42	2·18
·91	64·32	·91	4·73	·41	28·98	·41	2·13
·90	63·61	·90	4·68	·40	28·27	·40	2·08
·89	62·91	·89	4·62	·39	27·57	·39	2·02
·88	62·20	·88	4·57	·38	26·86	·38	1·97
·87	61·40	·87	4·52	·37	26·15	·37	1·92
·86	60·78	·86	4·47	·36	25·44	·36	1·87
·85	60·08	·85	4·42	·35	24·74	·35	1·82
·84	59·37	·84	4·36	·34	24·03	·34	1·76
·83	58·66	·83	4·31	·33	23·32	·33	1·71
·82	57·96	·82	4·26	·32	22·62	·32	1·66
·81	57·25	·81	4·21	·31	21·91	·31	1·61
·80	56 54	·80	4·16	·30	21 20	·30	1·56
·79	55·84	·79	4·10	·29	20·50	·29	1·50
·78	55·13	·78	4·05	·28	19·79	·28	1·45
·77	54·42	·77	4·00	·27	19.08	·27	1·40
·76	53·72	·76	3·95	·26	18·38	·26	1·35
·75	53·01	·75	3·90	·25	17·67	·25	1·30
·74	52·30	·74	3·84	·24	16·96	·24	1·24
·73	51·60	·73	3·79	·23	16·26	·23	1·19
·72	50·89	·72	3·74	·22	15·55	·22	1·14
·71	50·18	·71	3·69	·21	14·84	·21	1·09
·70	49·48	·70	3·64	·20	14·14	·20	1·04
·69	48·77	·69	3.58	·19	13·43	·19	·98
·68	48·06	·68	3·53	·18	12·72	·18	·93
·67	47·36	·67	3.48	·17	12·02	·17	·88
·66	46·65	·66	3·43	·16	11·31	·16	·83
·65	45·94	·65	3.38	·15	10·60	·15	·78
·64	45·24	·64	3.32	·14	9·90	·14	·72
·63	44·53	·63	3·27	·13	9·19	·13	·67
·62	43·82	·62	3·22	·12	8·48	·12	·62
·61	43·11	·61	3·17	·11	7·77	·11	·57
·60	42·41	·60	3·12	·10	7·07	·10	·52
·59	41·70	·59	3·06	·09	6·36	·09	·46
·58	40·99	·58	3·01	·08	5·65	·08	·41
·57	40·29	·57	2·96	·07	4·95	·07	·36
·56	39·58	·56	2·91	·06	4·24	·06	·31
·55	38·87	·55	2·86	·05	3·53	·05	·26
·54	38·17	·54	2·80	·04	2·83	·04	·20
·53	37·46	·53	2·75	.03	2·12	·03	·15
·52	36·75	·52	2·70	·02	1·41	·02	·10
·51	36·05	·51	2·65	.01	·71	·01	·05

Respecting table No. 2 very little need be said. It shows the pressure in pounds and decimal parts of a pound for one inch, and decimal parts of an inch. The weight of a cubic foot of water = 1000 ounces; therefore the pressure per square foot, one inch deep, will be 5·20 pounds. If the water-gauge stands at ·25, or a quarter of an inch, the pressure per square foot is 1·30 pounds. For the pressure to be equal to a quarter of a pound to the square inch, or 36 pounds per square foot, the difference of the water-level must be 6·92 inches. The water-gauge is very useful as a check on the furnaceman or fan, and also a tell-tale on the amount of friction in the air-courses, from whence may be inferred their state and condition.

Leveling with the Barometer.—To find the difference in elevation between two points, Belville's rule is the simplest and furnishes an approximately correct re-

sult. Add together the readings at each of the two points, also find the difference between the two readings; then as the sum of the two readings is to their difference, so is 55,000 ft. to the required difference in elevation.

Example.—If the barometrical reading at the foot of a mountain is 29·45 inches and at the top is 26·73 inches, what is the vertical height of the mountain?

$$29{\cdot}45 + 26{\cdot}73 = 56{\cdot}18 \text{ in.}; \text{ and } 29{\cdot}45 - 26{\cdot}73 = 2{\cdot}72 \text{ in.}$$

Sum. Diff. Feet. Feet.

Hence, as 56·18 : 2·72 :: 55,000 : 2662·87.

THE THERMOMETER

Thermometers are instruments designed to measure the changes in the temperature of the atmosphere, by the contraction and expansion of mercury and spirits; or they may be made entirely of metal, and the changes of temperature are then measured by the expansion and contraction of the sensitive metallic portion. These latter are known as aneroid thermometers. Fahrenheit's thermometer is the one most commonly used. By his scale the freezing-point of water at the sea-level is placed at 32° above zero; the boiling-point of water at sea-level is placed at 212° above zero, so that the space between these two points is divided into 180 degrees.

Reaumur and Centigrade thermometers are used on the continent of Europe. Of these two the first is generally used in Germany, and the second in France, but the latter is almost exclusively used by the scientists of all nations.

In the Reaumur thermometer, the freezing and boiling points are placed at 0° and 80° respectively. In the Centigrade the freezing and boiling points are placed at 0° and 100° respectively.

To convert Fahrenheit into Centigrade.—(1) Subtract 32 and divide the remainder by 1·8 thus:

If a Fahrenheit thermometer registers 167°, what will be the register by a Centigrade thermometer?

$$\frac{167 - 32}{1{\cdot}8} = 75° \text{ Cent.}$$

(2) Subtract 32, multiply the remainder by 5, and divide the product by 9, thus:

$$\frac{167 - 32 \times 5}{9} = 75° \text{ Cent.}$$

To convert Centigrade into Fahrenheit.—(1) Multiply by 1·8 and add 32, thus:

If the Centigrade thermometer registers 75°, what will be the register by a Fahrenheit thermometer?

$$75 \times 1{\cdot}8 + 32 = 167° \text{ Fahr.}$$

(2) Multiply by 9, divide by 5, and add 32, thus:

$$\frac{75 \times 9}{5} + 32 = 167° \text{ Fahr.}$$

To convert Fahrenheit into Reaumur.—(1) Subtract 32, and divide by 2·25, thus:

If the Fahrenheit thermometer registers 113°, what will be the register by the Reaumur thermometer?

$$\frac{113 - 32}{2{\cdot}25} = 36° \text{ Reau.}$$

(2) Subtract 32, multiply by 4, and divide by 9, thus:

$$\frac{113 - 32 \times 4}{9} = 36° \text{ Reau.}$$

To convert Reaumur into Fahrenheit.—(1) Multiply by 2·25 and add 32, thus:

If the Reaumur thermometer registers 36°, what will be the register by the Fahrenheit thermometer?

$$36 \times 2{\cdot}25 + 32 = 113° \text{ Fahr.}$$

(2) Multiply by 9, divide by 4, and add 32, thus:

$$\frac{36 \times 9}{4} + 32 = 113° \text{ Fahr.}$$

To convert Reaumur into Centigrade.—Multiply by 1·25, thus:

If a Reaumur thermometer registers 32°, what will be the register of a Centigrade thermometer?

$$32 \times 1{\cdot}25 = 40° \text{ Cent.}$$

To convert Centigrade into Reaumur.—Multiply by ·8, thus:

If a Centigrade thermometer registers 40° what will be the register of a Reaumur thermometer?

$$40 \times \cdot 8 = 32° \text{ Reau.}$$

VOLUME OF A GASEOUS BODY AT DIFFERENT TEMPERATURES.

The following table shows the changes of volume of a gaseous body consequent on given changes of temperature. In columns headed V are expressed in cubic inches, the volumes which 1,000 cubic inches of air at 32° Fahr. will have at the temperature in degrees Fahr., expressed in columns headed T, the air being maintained constantly at the same pressure.

T.	V.	T.	V.	T.	V.	T.	V.	T.	V.
—49	834·7	8	951·0	65	1067·3	122	1183·7	179	1300·0
—48	836·7	9	953·1	66	1069·4	123	1185·7	180	1302·0
—47	838·8	10	955·1	67	1071·4	124	1187·8	181	1304·1
—46	840·8	11	957·1	68	1073·5	125	1189·8	182	1306·1
—45	842·8	12	959·2	69	1075·5	126	1191·8	183	1308·2
—44	844·9	13	961·2	70	1077·6	127	1193·9	184	1310·2
—43	846·9	14	963·3	71	1079·6	128	1195·9	185	1312·2
—42	849·0	15	965·3	72	1081·6	129	1198·0	186	1314·3
—41	851·0	16	967·3	73	1083·7	130	1200·0	187	1316·3
—40	853·1	17	969·4	74	1085·7	131	1202·0	188	1318·4
—39	855·1	18	971·4	75	1087·8	132	1204·1	189	1320·4
—38	857·1	19	973·5	76	1089·8	133	1206·1	190	1322·4
—37	859·2	20	975·5	77	1091·8	134	1208·2	191	1324·5
—36	861·2	21	977·6	78	1093·9	135	1210·2	192	1326·5
—35	863·3	22	979·6	79	1095·9	136	1212·2	193	1328·6
—34	865·3	23	981·6	80	1098·0	137	1214·3	194	1330·6
—33	867·3	24	983·7	81	1100·0	138	1216·3	195	1332·6
—32	869·4	25	985·7	82	1102·0	139	1218·4	196	1334·7
—31	871·4	26	987·8	83	1104·1	140	1220·4	197	1336·7
—30	873·5	27	989·8	84	1106·1	141	1222·4	198	1338·8
—29	875·5	28	991·8	85	1108·2	142	1224·5	199	1340·8
—28	877·6	29	993·9	86	1110·2	143	1226·5	200	1342·9
—27	879·6	30	995·9	87	1112·2	144	1228·6	201	1344·9
—26	881·6	31	998·0	88	1114·3	145	1230·6	202	1346·0
—25	883·7	32	1000·0	89	1116·3	146	1232·7	203	1349·0
—24	885·7	33	1002·0	90	1118·4	147	1234·7	204	1351·0
—23	887·8	34	1004·1	91	1120·4	148	1236·7	205	1353·1
—22	889·8	35	1006·1	92	1122·4	149	1238·8	206	1355·1
—21	891·8	36	1008·2	93	1124·5	150	1240·8	207	1357·1
—20	893·9	37	1010·2	94	1126·5	151	1242·9	208	1359·2
—19	895·9	38	1012·2	95	1128·6	152	1244·9	209	1361·2
—18	898·0	39	1014·3	96	1130·6	153	1246·9	210	1363·3
—17	900·0	40	1016·3	97	1132·7	154	1249·0	211	1365·3
—16	902·0	41	1018·4	98	1134·7	155	1251·0	212	1367·3
—15	904·1	42	1020·4	99	1136·7	156	1253·0	213	1369·4
—14	906·1	43	1022·4	100	1138·8	157	1255·1	214	1371·4
—13	908·2	44	1024·5	101	1140·8	158	1257·1	245	1373·5
—12	910·2	45	1026·5	102	1142·9	159	1259·2	216	1375·5
—11	912·2	46	1028·6	103	1144·9	160	1261·2	217	1377·5
—10	914·3	47	1030·6	104	1147·0	161	1263·3	218	1379·6
— 9	916·3	48	1032·7	105	1149·0	162	1265·3	219	1381·6
— 8	918·4	49	1034·7	106	1151·0	163	1267·3	220	1383·7
— 7	920·4	50	1036·7	107	1153·1	164	1269·4	230	1404·1
— 6	922·5	51	1038·8	108	1155·1	165	1271·4	240	1424·5
— 5	924·5	52	1040·8	109	1157·1	166	1273·5	250	1444·9
— 4	926·5	53	1042·9	110	1159·2	167	1275·5	260	1465·3
— 3	928·6	54	1044·9	111	1161·2	168	1277·5	270	1485·7
— 2	930·6	55	1046·9	112	1163·3	169	1279·6	280	1506·1
— 1	932·7	56	1049·0	113	1165·3	170	1281·6	290	1526·5
0	934·7	57	1051·0	114	1167·3	171	1283·7	300	1546·9
1	936·7	58	1053·1	115	1169·4	172	1285·7	400	1751·0
2	938·8	59	1055·1	116	1171·4	173	1287·8	500	1955·1
3	940·8	60	1057·1	117	1173·5	174	1289·8	600	2159·2
4	942·9	61	1059·2	118	1175·5	175	1291·8	700	2363·3
5	944·9	62	1061·2	119	1177·6	176	1293·9	800	2567·3
6	947·0	63	1063·3	120	1179·6	177	1295·9	900	2773·5
7	949·0	64	1065·3	121	1181·6	178	1298·0	1000	2947·1

THE EXPANSION OF SOLIDS.

BY INCREASING THE TEMPERATURE FROM 32° TO 212°, THE LENGTH OF THE BAR AT 32° BEING 1·00000000

Glass Tube	1·00082800	Gold	1·00150000
Platinum	1·00088420	Lead	1·00286700
Antimony	1·00108300	Brass	1·00186671
Cast Iron	1·00111111	Wrought Iron	1·00125800
Steel	1·00118999	Zinc	1·00294200
Blistered Steel	1·00112500	Spelter Solder, Brass 2, Zinc 1	1·00205800
Steel, hardened	1·00122502	Soft Solder, Lead 2, Tin 1	1·00250800
Bismuth	1·00139200	Copper 8, Tin 1	1·00181700
Silver	1·00189000	Palladium	1·00100000
Tin	1·00217298		

THE EXPANSION OF LIQUIDS IN VOLUME FROM 32° TO 212° FAHR.

1000 parts of Water	become	1046
" " " Oil	"	1080
" " " Mercury	"	1018
" " " Spirits of Wine	"	1110
" " " Air	"	1373

EFFECTS OF HEAT ON VARIOUS METALS.

Metals.	Fahr. Deg.
Wrought Iron fuses	3300
Cast Iron melts	2400
Welding heat of Bar Iron	2420
Fine Gold melts	2100
Fine Silver "	1850
Copper "	1990
Brass "	1870
Iron red hot in daylight	1207
Lead melts	612
Mercury boils	600
Bismuth melts	476
Tin melts	445

The melting-points of metals cannot be determined exactly. We give the mean of the best authorities.

TO EXPLORE THE WORKINGS OF A MINE AFTER A SERIOUS EXPLOSION.

The shafts or slope, and the ventilating machinery should claim the first attention of those on the surface, and an effort should be made to reach the bottom as expeditiously as possible. Assistance from neighboring collieries, both in the way of skilled labor and advice, should also be requested. Should the shaft or slope need repairs before communication between top and bottom is restored, the person in charge on the surface should, in the meantime, see that props of the length in ordinary use, brattice-boards, brattice-cloth, and nails are brought to a convenient place for putting on the cage or car; and he ought also to collect all the tools likely to be required, such as axes, saws, hammers, etc. It is also important that rough tracings of the workings be prepared for the use of the leader of each squad of explorers. Officials will understand how useful these will be to those who are penetrating into workings about which every man of his squad may have been heretofore ignorant.

When the explorers have arrived at the bottom and are ready to proceed, there should be for each section, if more than one is operated upon, two managers, each having his own squad of men, and his own particular duty to do. One may take charge of restoring the ventilation, the inspection of the workings, and the clearing of the roads; the other may appoint and have charge of the bottom man, the conveying of material, and the detailing of stretcher companies where required. They can consult and help each other in every difficulty; but system is necessary if the work is to be done in the shortest possible time.

The manager who has charge of the men in front should appoint two experienced men with good nerves to act as foremen, instructing them to inspect and report to him the condition of the workings within a short radius. He should then form the rest of his men into, say, three squads of three each, who will work together at stoppings or falls until separated by him, or until the end of the shift. Being near the bottom, it will probably be

found that all is clear for three or four breast or stoop-lengths, and stoppings are required to be put up. Material will be required for this, and when the cage is first sent to the top for it, it should not be kept there to enable the top man to put on a big load, but it should be sent down with all despatch, loaded with a half-dozen each of props and brattice-boards, with one piece of cloth and nails. This will allow a start to be made, and will prevent the anxious men from worrying over, what to them is, an unaccountable delay. Larger loads can be sent down in subsequent trips. For convenience in carrying, the brattice cloth may be cut in lengths to suit the gangways or headings with two or three feet to spare. Squad No. 1 should be detailed to the first stopping. This may be put up with boards at top and bottom and cloth between. If the air-current is strong, a few of the following stoppings may be put up by squads two and three, with cloth only stretched between two props. These can be very rapidly put up and will drive the ventilation forward, thus allowing the firemen to extend rapidly the area of inspection. These stoppings can be completed by No. 1 detail. In a short time it may become impossible to proceed in this manner. The foul air will in all probability become more difficult to dislodge, and eventually one detail may be able to put up stoppings as quickly as the fire or choke-damp can be carried off. Part of what may be called the ventilating detail can now be transferred to the bearer detail, the duties of the latter having become heavier as the stoppings advanced. It is not an easy task to carry props long distances in a stooping posture, and when to that is added, it may be, the carrying out of the living or dead bodies, the men begin to fag very soon. But the person in charge here must see that the forward party are kept in material for stoppings so that no delay may occur on that account. A system of staging gives relief to the carrying parties.

To conclude with a few general remarks. Let those who have never yet assisted to explore a mine after an explosion, be assured of this that the chief requisites in a leader are a capacity for hard work, and the ability to organize his men into a system, however roughly, whereby work will be best forwarded. It will not speed the work to say to a dozen or more men generally do this or that; neither is it beneficial to allow all the workmen to discuss matters and suggest plans. Those in charge ought to arrange what is to be done. Anything else results in noise and confusion. And let men who are sent from other collieries take with them their own tools and lamps. Those in charge ought to take note of the position, &c., of bodies found, and of every point which is likely to throw light on the cause or origin of the explosion. This can be more correctly done before the roads are disturbed by dust and travel. These notes might not only be the means of ascertaining the cause of explosion, but also of pointing out a way of prevention in the future.

TREATMENT OF PERSONS OVERCOME BY GAS.

Miners are exposed to asphyxia when the circulation of the air is not sufficiently active, when the mine exhales a quantity of deleterious gas, when they imprudently penetrate into ancient and abandoned workings, and when there is an explosion.

The symptoms of asphyxia are sudden cessation of the respiration, of the pulsations of the heart, and of the action of the senses; the countenance is swollen, and marked with reddish spots, the eyes are protruded, the features are distorted, and the face is often livid, &c.

The best and first remedy to employ, and in which the greatest confidence ought to be placed, is the renewal of the air necessary for respiration. In succession:

1. Promptly withdraw the asphyxiated person from the deleterious place, and expose him to pure air.

2. Loosen the clothes round the neck and chest; and dash cold water in the face and on the chest.

3. Attempts should be made to irritate the pituitary membrane with the feathered end of a quill, which should be gently moved in the nostrils of the insensible person, or to stimulate it, with a bottle of volatile alkali placed under the nose.

4. Keep up the warmth of the body, and apply mustard plasters over the heart and round the ankles.

5. If these means fail to produce respiration Dr. Sylvester's method of producing artificial respiration should be tried, as follows:

Place the patient on the back on a flat surface inclined a little upwards from the feet; raise and and support the head and shoulders on a small firm cushion or folded article of dress placed under the shoulder-blades. Draw

forward the patient's tongue and keep it projecting beyond the lips; an elastic band over the tongue and under the chin will answer this purpose, or a piece of string or tape may be tied round them, or by raising the lower jaw the teeth may be made to retain the tongue in that position. Remove all tight clothing from about the neck and chest, especially the braces. Then standing at the patient's head, grasp the arms just above the elbows, and draw the arms gently and steadily upwards above the head, and keep them stretched upwards for two seconds (by this means air is drawn into the lungs). Then turn down the patient's arms and press them gently and firmly for two seconds against the sides of the chest (by this means air is pressed out of the lungs). Repeat these measures alternately, deliberately, and perseveringly about fifteen times in a minute, until a spontaneous effort to respire is perceived; immediately upon which cease to imitate the movements of breathing, and proceed to induce circulation and warmth.

6. To promote warmth and circulation rub the limbs upwards with firm grasping pressure and energy using handkerchiefs, flannels, &c. Apply hot flannels, bottles of hot water, heated bricks, &c., to the pit of the stomach, the arm pits, between the thighs, and to the soles of the feet.

7. On the restoration of life a teaspoonful of warm water should be given; and then, if the power of swallowing has returned, small quantities of wine, warm brandy and water, or coffee should be administered.

8. These remedies should be promptly applied, and, as death does not certainly appear for a long time, they ought only to be discontinued when it is clearly confirmed. Absence of the pulsation of the heart is not a sure sign of death, neither is the want of respiration.

TREATMENT OF INJURED PERSONS.

By W. F. Brady, M. D., Scranton, Pa.; Late Assistant Surgeon State Hospital for Injured Persons, Ashland, Pa.

SEND FOR A PHYSICIAN.

The dangers to be feared in case of wounds, are: *Shock or collapse, loss of blood, and unnecessary suffering in the moving of the patient.*

In shock, the injured person lies pale, faint and cold, sometimes insensible, with feeble pulse and superficial breathing. The cause of death in case of a shock is arrest of heart action, produced by the suspension of the functions of the brain and spinal cord. In treatment, the two most important parts are:

1. The position of the injured person.
2. The application of external warmth.

The injured person should at once be placed in a recumbent position, his head resting on a plane lower than that of his trunk, legs, and feet. He should be well wrapped up and protected from the chilling influences of external air. When there is danger of immediate death, stimulants should be given; in all other conditions of shock, stimulants are injurious.

Loss of blood.—Two conditions present themselves: (1) The bleeding is arrested spontaneously or otherwise, but the injured person presents all the symptoms of loss of blood. (2) The injured person is actually bleeding, and he is, or is not, suffering from loss of blood.

In the first condition life is threatened by anaema of brain and spinal cord, and all the efforts of treatment are to direct the flow of whatever quantity of blood may still remain in the body, to the vital centres in the brain and spinal cord. This is most efficiently done by placing the injured person in a recumbent position, with his head resting on a plane somewhat lower than that of his trunk and legs. In graver cases constricting bands should be applied to both arms, as near the shoulders as possible, and to both thighs, as near the abdomen as possible. This last manœuvre directs the entire quantity of blood in the body to the suffering centres, the centres of life itself. Stimulants may be sparingly administered.


Fig. 1.

If there is bleeding, do not try to stop it by binding up the wound. *The current of blood to the part must be checked.* To do this find the artery, by its beating; lay a firm and even compress or pad (made of cloth or rags rolled up, or a round stone or piece of wood well wrapped) *over the artery* (see Fig. 1). Tie a handkerchief around the limb and compress; put a bit of stick through the handkerchief and twist the latter up until it is *just tight enough to stop the*

bleeding, then put one end of the stick under the handkerchief to prevent untwisting, as in Fig. 2.

The artery in the thigh runs along the inner side of the muscle in front near the bone (as shown by dotted line in Fig. 3). A little above the knee it passes to the back of the bone. In injuries at or above the knee apply the compress higher up, on the inner side of the thigh, (at the point P, Fig. 3), with the knot on the outside of the thigh.

FIG. 2.

When the leg is injured below the knee, apply the compress at the back of the thigh, just above the knee at P, Fig. 4, and the knot in front as in Figs. 1 and 2.

The artery in the arms runs down the inner side of the large muscle in front, quite close to the bone, as shown by dotted line; low down it is further forward towards the bend of the elbow. It is most easily compressed a little above the middle, (P, Fig. 5). Care should be taken to examine the limb from time to time, and to lessen the compression if it becomes cold or purple; tighten up the handkerchief again if the bleeding begins afresh.

FIG. 3.

To transport a wounded person comfortably.—Make a soft and even bed for the injured part of straw, folded, blankets, quilts or pillows, laid on a board, with side pieces of board nailed on, when this can be done. If possible, let the patient be laid on a door, shutter, settee or some firm support, properly covered. Have sufficient force to lift him steadily, and let those that bear him *not* keep step.

Should any important arteries be opened apply the handkerchief as recommended. Secure the vessel by a surgeon's dressing forceps, or by a hook, then have a silk ligature put around the vessel, and tighten tight.

FIG. 4.

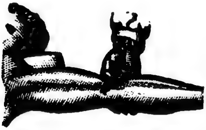


FIG. 5.

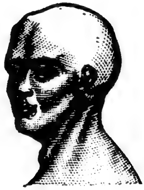


FIG. 6.

Should the bleeding be from arterial vessels of small size, apply the *persulphate of iron*, either in tincture or in powder, by wetting a piece of lint or sponge with the solution; then, after bleeding ceases, apply a compress against the parts to sustain them during the application of the persulphate of iron, and to prevent further bleeding should it occur.

The persulphate of iron should be kept in or about all working-places.

Bleeding from scalp wounds.—A pad or compress is placed immediately before the ear over the region marked (FIG. 6) by a dotted line. The compress is firmly secured by a handkerchief. If this does not arrest bleeding a similar compress on the opposite side should be applied. Should the bleeding issue from a wound of the posterior, or back part of head, a compress should be placed behind the ear over the region marked (in Fig. 6) by the dotted line, and firmly secured by a handkerchief or bandage.

TABLES SHOWING DISTANCE FROM CENTER TO CENTER OF BREASTS OR CHAMBERS ALONG GANGWAYS OR ENTRIES.

Width of Breast + Width of Pillar = 20 feet.

Angle between Gangway and Breasts.	Distance from Center to Center, along Gangway, in feet.
90°	20·0
85°	20·0
80°	20·3
75°	20·7
70°	21·2
65°	22·0
60°	23·0
55°	24·4
50°	25·8
45°	28·2
40°	31·1
35°	34·9
30°	40·0
25°	47·3
20°	58·5
15°	77·4
10°	115·2
5°	229·5

Width of Breast + Width of Pillar = 25 feet.

Angle between Gangway and Breasts.	Distance from Center to Center, along Gangway, in feet.
90°	25·0
85°	25·1
80°	25·4
75°	25·9
70°	26·6
65°	27·6
60°	28·9
55°	30·5
50°	32·6
45°	35·4
40°	38·9
35°	43·6
30°	50·0
25°	59·2
20°	73·1
15°	96·6
10°	144·0
5°	286·9

Width of Breast + Width of Pillar = 30 feet.

90°	30·0
85°	30·1
80°	30·5
75°	31·1
70°	31·9
65°	33·1
60°	34·6
55°	36·6
50°	39·2
45°	42·4
40°	46·7
35°	52·3
30°	60·0
25°	71·0
20°	87·7
15°	115·9
10°	172·8
5°	344·2

Width of Breast + Width of Pillar = 35 feet.

90°	35·0
85°	35·1
80°	35·5
75°	36·2
70°	37·2
65°	38·6
60°	40·4
55°	42·7
50°	45·7
45°	49·5
40°	54·5
35°	61·0
30°	70·0
25°	82·8
20°	102·4
15°	135·3
10°	201·6
5°	401·6

Width of Breast + Width of Pillar = 40 feet.

90°	40·0
85°	40·2
80°	40·6
75°	41·4
70°	42·6
65°	44·1
60°	46·2
55°	48·8
50°	52·2
45°	56·6
40°	62·2
35°	69·7
30°	80·0
25°	94·6
20°	117·0
15°	154·5
10°	230·4
5°	459·0

Width of Breast + Width of Pillar = 45 feet.

90°	45·0
85°	45·2
80°	45·7
75°	46·6
70°	47·9
65°	49·6
60°	52·0
55°	54·9
50°	58·7
45°	63·6
40°	70·0
35°	78·5
30°	90·0
25°	106·5
20°	131·6
15°	173·9
10°	259·2
5°	516·3

TABLES SHOWING DISTANCE FROM CENTER TO CENTER OF BREASTS OR CHAMBERS ALONG GANGWAYS OR ENTRIES.

Width of Breast + Width of Pillar = 50 feet.		Width of Breast + Width of Pillar = 55 feet.	
Angle between Gangway and Breasts.	Distance from Center Center, along Gangway, in feet.	Angle between Gangway and Breasts.	Distance from Center to Center, along Gangway, in feet.
90°	50·0	90°	55·0
85°	50·1	85°	55·2
80°	50·6	80°	55·8
75°	51·2	75°	56·9
70°	53·1	70°	58 5
65°	55·1	65°	60·7
60°	57·6	60°	63·5
55°	60·9	55°	67·1
50°	65·1	50°	71·8
45°	70·6	45°	77·8
40°	77·6	40°	85·6
35°	87·0	35°	95·9
30°	100·0	30°	110·0
25°	118·1	25°	127·2
20°	145·9	20°	160·8
15°	192·8	15°	212·5
10°	287·3	10°	816·7
5°	572·5	5°	631·1

Width of Breast + Width of Pillar = 60 feet.		Width of Breast + Width of Pillar = 65 feet.	
90°	60 0	90°	65·0
85°	60·2	85°	65·3
80°	60·9	80°	66·0
75°	62·1	75°	67·3
70°	63·9	70°	69·2
65°	66·2	65°	71·7
60°	69·3	60°	75·1
55°	73·3	55°	79·4
50°	78·3	50°	84·9
45°	84·9	45°	91·9
40°	93·4	40°	101·2
35°	104·6	35°	113·4
30°	120·0	30°	130·0
25°	142·0	25°	153·8
20°	175·5	20°	190·1
15°	231·9	15°	251·2
10°	345·6	10°	874·4
5°	688·5	5°	745·8

Width of Breast + Width of Pillar = 70 feet.		Width of Breast + Width of Pillar = 75 feet.	
90°	70·0	90°	75·0
85°	70·3	85°	75·3
80°	71·1	80°	76·2
75°	72·5	75°	77·7
70°	74·5	70°	79·8
65°	77·2	65°	82·8
60°	80·8	60°	86·6
55°	85·5	55°	91·6
50°	91·4	50°	97·9
45°	99·0	45°	106·1
40°	109·0	40°	116·7
35°	122·1	35°	180·8
30°	140·0	30°	150·0
25°	165·7	25°	177·5
20°	204·7	20°	219·3
15°	270·5	15°	289·8
10°	403·1	10°	432·0
5°	803·2	5°	860·5

SPIRAL WELD STEEL TUBES.

Manufactured by the Spiral Weld Tube Co., 43 John St., New York.

The strength of spirally welded tubing is, of course, in proportion to the thickness of metal used and the diameter. The following table shows the proof strength and ultimate strength of spirally welded steel pipes of various diameters, from 6 inches to 24 inches, and of different thicknesses of metal, as shown by the commercial designations; "Light," "Standard," "Heavy," and "Extra Heavy." By "elastic limit" is meant the pressure per square inch which the pipe will carry without a stretch or distortion great enough to produce a permanent set; by "ultimate strength" is meant the pressure per square inch required to burst the pipe:

The couplings, etc., of spirally welded tubing are specially designed, and are strong, light, and convenient.

LIGHT SPIRAL WELD TUBES.

Diameter.	Approximate Weight Per Foot.	Elastic Limit Per Square Inch.	Ultimate Strength Per Square Inch.
Inches.	Pounds.	Pounds.	Pounds.
16	17·33	415	674
18	18·71	369	599
20	20·68	332	539
22	22·60	302	490
24	24·61	277	449

STANDARD SPIRAL WELD TUBES.

6	4·66	866	1,408
8	6·22	650	1,056
10	9·84	664	1,079
12	11·81	553	899
14	14·27	474	771
16	21·53	545	886
18	24·21	484	787
20	26·37	436	709
22	29·30	396	644
24	31·89	363	590

HEAVY SPIRAL WELD TUBES.

6	5·87	1,106	1,798
8	7·88	830	1,349
10	12·83	872	1,417
12	15·41	727	1,181
14	18·47	623	1,012
16	26·19	670	1,088
18	29·34	596	968
20	32·25	436	871
22	35·58	587	791
24	38·78	446	726

EXTRA HEAVY SPIRAL WELD TUBES.

12	18·89	893	1,451
14	22·54	765	1,244
16	31·89	825	1,341
18	35·76	733	1,192
20	39·63	660	1,073
22	43·43	600	975
24	47·36	550	894

HYDROSTATICS.

Hydrostatics treats of the equilibrium of liquids, and of their pressures on the walls of vessels containing them; the science depends on the way in which the molecules of a liquid form a mass under the action of gravity and molecular attraction, the latter of which is so modified in liquids as to give them their state of liquidity. While the particles of a liquid cohere, they are free to slide upon one another without the least apparent friction; and it is this perfect mobility that gives them the mechanical properties considered in hydrostatics.

The fundamental property may be thus stated: *When a pressure is exerted on any part of the surface of a liquid, that pressure is transmitted undiminished to all parts of the mass, and in all directions.* This is a physical axiom, and on it are based nearly all the principles of hydrostatics.

Equilibrium of liquids.—This is a property of liquids that can be easily demonstrated, and examples are frequently seen. Thus, if two barrels are connected at the bottom with a pipe, and water is poured in one until it reaches to within a foot of the top, the water in the other will be found to have attained the same height.

Pressure of liquids on surfaces.—The general proposition on this point is as follows: *The pressure of a liquid on any surface immersed in it, is equal to the weight of a column of the liquid whose base is the surface pressed, and whose height is the perpendicular depth of the centre of gravity of the surface below the surface of the liquid.* The pressure thus exerted is independent of the shape or size of the vessel or cavity containing the liquid.

The pressure of a liquid against any point of any surface, either curved or plane, is always perpendicular to the surface at that point.

At any given depth the pressure of a liquid is equal in every direction, and is in direct proportion to the vertical depth below the surface.

The weight of a cubic foot of fresh water, at ordinary temperature of the atmosphere, that is, from 32° Fahr. to 80° Fahr., is usually assumed at 62.5 lbs. This is a trifle more than the actual weight, but is sufficiently close for purposes of calculation.

To find the pressure exerted by quiet water against the side of a gangway or heading.—Multiply the area of the side in square feet by the perpendicular distance from the surface of the water to a point equi-distant between the top and bottom of the submerged heading or gangway, and multiply the product by 62.5. The result will be the pressure in lbs., exclusive of atmospheric pressure. This latter need not be considered in ordinary mining work.

EXAMPLE.—If an abandoned colliery, opened by a slope on a pitch of 25° and 100 yds. long, is allowed to fill with water, what is the average pressure exerted on each square foot of the lower rib of the gangway, assuming that the gangways were driven dead level, and that the length of the slope was measured to a point on the lower rib equi-distant between top and bottom of gangway. We here have a perpendicular height of water = 300 × sine of 25° = 126·78 ft. Then the pressure on each square foot of the lower rib of gangway = 126·78 × 62·5 lbs., or the weight of 1 cubic ft., or a pressure on each square foot of surface of 7,923·75 lbs., or over 3½ gross tons. The total pressure exerted along the gangway may readily be found by multiplying the 7,923·75 lbs. by the number of square feet of the lower rib against which it rests.

To find the total pressure of quiet water against and perpendicular to any surface whatever, as a dam, embankment, or the bottom side or top of any containing vessel, water pipe, etc., no matter whether said surface be vertical, horizontal or inclined; or whether it be flat or curved; or whether it reach to the surface of the water or be entirely below it:

Multiply the area, in square feet, of the surface pressed, by the vertical depth in feet of its centre of gravity below the surface of the water, and this product by 62·5. The result will be the pressure in lbs.

Thus, assuming that in the annexed 3 figures the depth of water in each dam was 12 ft. and the wall or embankment was 50 ft. long, then in *Fig.* 1 the total pressure would equal $12 \times 50 \times 6 \times 62{\cdot}5 = 225{,}000$ lbs.

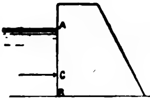


Fig. 1.

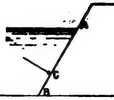


Fig. 2.

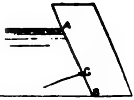


Fig. 3.

In *Figs.* 2 and 3 the walls or embankments being inclined, expose a greater surface to pressure, say 18 ft. from A to B. Then the total pressure equals $18 \times 50 \times 6 \times 62.5 = 337{,}500$ lbs.

Now, the results obtained are the *total* pressures without regard to direction. In *Fig.* 1 the total pressure calculated, or 225,000 lbs., is horizontal, tending either to overturn the wall or make it slide on its base. The centre of pressure is at C or ⅓ of the vertical depth from the bottom.

In *Fig.* 2 the pressure is exerted in two directions; one pressure, acting horizontally, tends to overthrow or slide the wall, while the other, acting vertically, tends to hold it in place.

In *Fig.* 3 the pressure is also exerted in two directions; one pressure, acting horizontally, tends to overthrow or slide the wall, while the other tends to lift.

So long as the vertical depth of water remains the same, the *horizontal* pressure remains the same, no matter what inclination is given the wall. Thus, in *Figs.* 2 and 3, the horizontal pressure is the same as in *Fig.* 1, or 225,000 lbs.

The total pressure of the water is distributed over the entire depth of the submerged part of the back of the wall, and is least at the top, gradually increasing toward the bottom. But so far as regards the united action of every portion of it, in tending to overthrow the wall, considered as a single mass of masonry, incapable of being bent or broken, it may all be assumed to be applied at C, which is ⅓ of the vertical depth from the bottom in *Fig.* 1, or, what is the same thing, ⅓ of the slope distance from the bottom in *Figs.* 2 and 3.

No matter how much water is in a dam or vessel, the pressure remains the same, so long as the area pressed and the vertical depth of its centre of gravity below the level surface of the water remains unchanged. Thus, if the water in dam shown in *Fig.* 1 extended back 1 mile, it would exert no more pressure against the wall than if it extended back only 1 foot.

In any two vessels having the same base, and containing the same *depth* of water, no matter what quantity, the pressures on the bases are equal. Thus, if *Figs.* 4 and 5 have the same base and be filled with water, the pressure on the bases will be equal. This fact, that the pressure on a given surface, at a given depth, is independent of the quantity of water, is called the hydrostatic paradox.

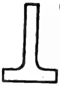


Fig. 4.

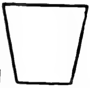


Fig. 5.

As the pressure of water against any point is at right angles to the surface at that point, it follows that props or other strengthening material for the strengthening of such structures as a sloping dam, should be so placed as to offer the greatest resistance in a line at right angles to the sloping surface, and these supports should be strongest and closest together at the bottom. For the same reason the hoops on a circular tank should be strongest and closest at the bottom.

Transmission of pressure through water.—Water, in common with other liquids, possesses the important property of transmitting pressure equally in all directions. Thus, if a vessel is constructed with two cylinders, the area of one being 10 square inches, and that of the other 100 square inches, and the vessel is filled with water (see *Fig.* 6), and pistons fitted to the cylinders, a pressure of 100 lbs. applied at A will balance 1,000 lbs. at B. This is the principle of the hydrostatic press.

Air and other gaseous fluids transmit pressure equally in all directions, like liquids; but not as rapidly.

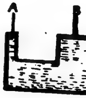


Fig. 6.

To find the pressure at any given depth.—For lbs. per square inch, multiply depth in feet by ·434. For lbs. per square foot, multiply depth in feet by 62·5. For tons per square foot, multiply depth in feet by ·0279.

The pressure per square foot at different depths increases directly as the depths. The total pressure against a plane 1 ft. wide at different depths increases as the square of the depths.

TABLE SHOWING PRESSURE IN LBS. PER SQUARE FOOT AT DIFFERENT VERTICAL DEPTHS, AND ALSO THE TOTAL PRESSURE AGAINST A PLANE 1 FOOT WIDE EXTENDING VERTICAL FROM THE SURFACE OF THE WATER TO THE SAME DEPTHS.

Depth in feet.	Pressure in lbs. pr. sq. ft.	Total Pressure in lbs.	Depth in feet.	Pressure in lbs. pr. sq. ft.	Total Pressure in lbs.	Depth in feet.	Pressure in lbs. pr. sq. ft.	Total Pressure in lbs.
1	62.5	31	27	1,687	22,781	65	4,062	132,025
2	125	125	28	1,750	24,500	70	4,375	153,124
3	187	281	29	1,812	26,281	75	4,687	175,779
4	250	500	30	1,875	28,125	80	5,000	200,000
5	312	781	31	1,937	30,031	85	5,312	225,775
6	375	1,125	32	2,000	32,000	90	5,625	253,124
7	437	1,531	33	2,062	34,031	95	5,937	282,025
8	500	2,000	34	2,125	36,125	100	6,250	312,500
9	562	2,531	35	2,187	38,281	110	6,875	378,124
10	625	3,125	36	2,250	40,500	120	7,500	450,000
11	687	3,781	37	2,312	42,781	130	8,125	528,100
12	750	4,500	38	2,375	45,125	140	8,750	612,496
13	812	5,281	39	2,437	47,531	150	9,375	703,116
14	875	6,125	40	2,500	50,000	160	10,000	800,000
15	937	7,031	41	2,562	52,531	170	10,625	903,100
16	1,000	8,000	42	2,625	55,125	180	11,250	1,012,496
17	1,062	9,031	43	2,687	57,781	190	11,875	1,128,100
18	1,125	10,125	44	2,750	60,500	200	12,500	1,250,000
19	1,187	11,281	45	2,812	63,281	225	14,062	1,582,025
20	1,250	12,500	46	2,875	66,125	250	15,625	1,953,100
21	1,312	13,781	47	2,937	69,031	275	17,187	2,363,275
22	1,375	15,125	48	3,000	72,000	300	18,750	2,812,500
23	1,437	16,531	49	3,062	75,031	350	21,875	3,828,100
24	1,500	18,000	50	3,125	78,125	400	25,000	5,000,000
25	1,562	19,531	55	3,437	94,531	450	28,120	6,328,100
26	1,625	21,125	60	3,750	112,500	500	31,250	7,812,500

Pressure of water in pipes.—As water exerts a pressure equally in all directions, it is important that in pipe lines the pipe should be sufficiently thick to assure strength enough to resist a bursting pressure. In ordinary practice the thickness of cast iron water pipes of different bores is calculated by Mr. J. T. Fanning's formula (see p. 454, Hydraulic Engineering), which is as follows:

$$\left.\begin{array}{l}\text{Thickness}\\ \text{in inches.}\end{array}\right\} = \frac{(\text{pressure in lbs. pr. sq. in.} + 100) \times \text{bore in ins.}}{.4 \times \text{ultimate tensile strength.}} + .333\left(1 - \frac{\text{bore in ins.}}{100}\right)$$

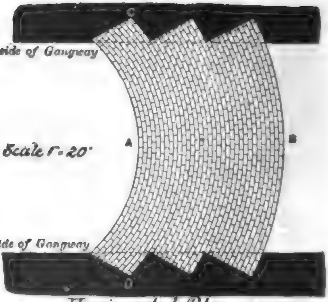
This formula, worked out for different heads and different sizes of bore, yields the following results:

Head in ft....	50	100	200	300	500	1,000
Pressure in lbs. per sq. in.	21·7	43·4	86·8	130	217	434
Bore, in ins.	Thickness of Pipe, in inches.					
2	·36	·37	·38	·39	·42	·48
3	·37	·38	·40	·42	·45	·54
4	·39	·40	·42	·45	·50	·61
6	·41	·43	·47	·50	·57	·75
8	·45	·47	·52	·57	·66	·90
10	·47	·50	·56	·62	·74	1·04
12	·49	·53	·60	·67	·82	1·18
16	·55	·60	·70	·79	·98	1·46
18	·57	·63	·74	·85	1·06	1·60
20	·61	·67	·79	·91	1·15	1·75
24	·66	·73	·87	1·02	1·30	2·03
30	·74	·83	1·01	1·19	1·55	2·46
36	·82	·93	1·15	1·36	1·80	2·88
48	·98	1·13	1·42	1·70	2·28	3·73

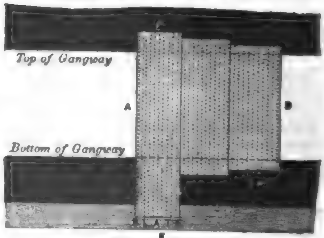
In the above table the ultimate tensile strength of cast iron is taken at 18,000 lbs. per square inch. The addition of 100 lbs. to the pressure is made to allow for water-ram. *The valves of water pipes should be closed slowly*, and the necessity of this increases as the pipes increase in diameter. If this rule is not observed, the momentum of the running water is arrested suddenly, and a great pressure is created against the pipes in all directions, and throughout the entire length of the line above the valve, even if it be many miles, and there is danger of their bursting at any point. For this reason stop-gates are shut by screws, because they prevent any very sudden closing; but in pipes of large diameters, even the screws must be worked very slowly to prevent bursting.

Compressibility of liquids.—Liquids are not entirely incompressible, but they are so nearly so, that for most purposes they may be considered as incompressible. The bulk of water is diminished about $\frac{1}{1000}$ by a pressure of 324 lbs. per square inch, or 22 atmospheres; varying slightly with its temperature. It is perfectly elastic, regaining its original bulk when the pressure is removed.

CONSTRUCTION OF DAMS IN MINES.



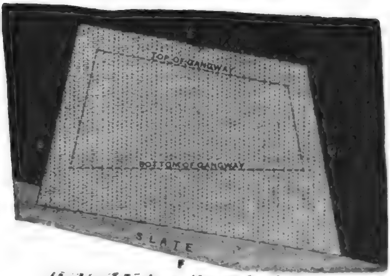
Horizontal Plan



Vertical Section through A B
Scale 20', 1"

When, for any cause, it becomes necessary to construct dams in mines that must be flooded, they must be so designed and constructed of such material as will ensure their stability under the utmost pressure that can reach them. Examples of this kind of work are few. In 1881 it was necessary, owing to a mine fire, to flood a portion of the Kehley's Run Colliery at Shenandoah, Pa. Owing to the fact that it was necessary to do this without endangering the men employed in two neighboring collieries, working the same vein, one of which was connected with Kehley's Run and the other separated only by small pillars, great skill was required in the locating and construction of the water barriers. This work was successfully accomplished by Heber S. Thompson, Esq., Chief Engineer of the Girard estate, on which the colliery was located. The colliery was working its third level in the Mammoth vein, which dipped in this locality from 20° to 30° south. The fire was in the middle level, and as Mr. Thompson aptly states it, the attempt to drown out a portion of the workings "was like an attempt to extinguish a fire on the second floor of a three-storied house, by filling it full of water from the first floor to the roof. It was necessary to wall up not only the windows of the second and third stories where the fire was, but the windows of the first floor and doors communicating with neighboring houses. Then, too, the walls of the first story had to be carefully examined as to their ability to hold together under the pressure of the water extending to the roof of the building." This meant the construction of dams in both the middle and lower levels. Those in the middle level, besides confining the water to a certain area on that level, were so constructed as to relieve those of the lower level from the pressure of the water between the middle level and the surface, and those on the lower level were constructed to withstand the pressure of the water between the middle and lower levels, with sufficient additional strength to withstand the pressure of the total height of water, if such contingency should occur as to make it necessary. The accompanying plans, drawn to scale, show the form of construction and the manner in which the

walls were keyed into the solid coal. These walls were built of brick and cement, and were 15 ft. thick, built in sections of 5 ft. each, arched toward the pressure, with each section fitting against and lapping over the inside of it, on sides, top and bottom. The outer section was cut into the coal on the sides and on top and bottom, deeper than the other two, in order to catch any slip or crevice that might have escaped the others. On the low side, that toward which the vein dipped, the depth of the cutting below the level of the gangway was 8½ ft. After one section of each dam was built, the workmen erected a section of one of the others, thus allowing the cement to set thoroughly hard before another section was added.



Vertical Section through C D
Scale 20' = 1"

The vertical height from the lower to the middle level was 119 ft., and as the dams were 13 ft. high, the average pressure per square foot was about 70,000 lbs., or a little over 31 gross tons.

The plans shown are excellent examples of this class of work, and are given as a guide to others who may have occasion to carry out similar work.

HYDRAULICS.

Hydraulics treats of liquids in motion, and in this, as in Hydrostatics, water is taken as the type. In theory its principles are the same as those of falling bodies, but in practice they are so modified by various causes that they cannot be relied upon except as verified by experiment. The discrepancy arises from changes of temperature which vary the fluidity of the liquid, from friction, the shape of the orifice, etc. As we shall deal with water only, the first cause may be thrown aside as of little account.

In theory *the velocity of a jet* is the *same as that of a body falling from the surface of the water.*

To find the theoretical velocity of a jet of water.—Let v = the velocity, g = the acceleration of gravity (32·16 ft.) and d = the distance of the orifice below the surface of the water.

Then $v = \sqrt{2gd}$, or v = the square root of twice the product of $g \times d$.

Example.—The depth of water above the orifice is 64 ft.; what is the velocity?

Substituting 64 for d, and 32·16 for g, we have, $v = \sqrt{2 \times 32{\cdot}16 \times 64}$ or 64·16.

To find the theoretical quantity of water discharged in a given time.—Multiply the area of the orifice by the velocity of the water, and that product by the number of seconds.

Example.—What quantity of water will be discharged in five seconds from an orifice having an area of 2 sq. ft., at a depth of 16 ft.?

$\sqrt{2 \times 32{\cdot}16 \times 16} \times 2 = 64{\cdot}16$ cu. ft., or the amount discharged in one second, and in five seconds the amount will be $5 \times 64{\cdot}16 = 320{\cdot}8$ cu. ft.

The above rules are only theoretical and are only useful as foundations on which to build practical formulæ.

Flow of water through orifices.—The standard orifice, or an orifice so arranged that the water in flowing from it touches only a line, as would be the case in flowing through a hole in a very thin plate, is used for the measurement of water.

The contraction of the jet, which always occurs when water issues from a standard orifice, is due to the circumstance that the particles of water as they approach the orifice move in converging directions and that these directions continue to converge for a short distance beyond the plane of the orifice. This contraction causes only the inner corner of the orifice to be touched by the escaping water. This contraction takes place in orifices of any shape, and its cross section is similar to the orifice until the place of greatest contraction is passed. Owing to this contraction the actual discharge from an orifice is always less than the theoretic discharge.

The coefficient of contraction.—The coefficient of contraction is the number by which the area of the orifice is to be multiplied in order to find the area of the least cross section of the jet. In this way by experiment this coefficient has been found to be about 0·62 (Merriman's Hydraulics) or in other words, the minimum cross section of the jet is 62% of the cross section of the orifice.

The coefficient of velocity.—The coefficient of velocity is the number by which the theoretical velocity of flow from the orifice is to be multiplied in order to find the actual velocity at the least cross section of the jet. This may be taken for practical work as 0·98; or, in other words the actual flow at the contracted section is 98% of the theoretical velocity.

The coefficient of discharge.—The coefficient of discharge is the number by which the theoretical discharge is to be multiplied in order to obtain the actual discharge. This has been found by thousands of experiments to be equal to the product of the coefficients of contraction and velocity, and for practical work it may be taken as 0·61; or the actual discharge from standard orifices is 61% of the theoretic discharge.

The miner's inch.—The miner's inch may be roughly defined to be the quantity of water which will flow in one minute from a vertical standard orifice one inch square, when the head on the center of the orifice is 6½ inches. This equals 1·53 cu. ft., and the mean value of the miner's inch is therefore about 1·5 cu. ft. per minute.

Suppression of the contraction.—When a vertical orifice has its lower edge at the bottom of a reservoir, the particles of water flowing through its lower portion move in lines nearly perpendicular to the plane of the orifice, and the contraction of the jet does not form on the lower side. The same thing occurs in a lesser degree when the lower edge of the orifice is within a distance of three times its least diameter from the bottom. The suppression of contraction will occur on the side if it is placed within a distance of three times its least diameter from the side of a reservoir. The suppression of contraction being the greater the nearer the orifice is to the side. By rounding the edge of the orifice sufficiently the contraction can be completely suppressed, and the discharge can be increased. As stated before, the value of the coefficient of contraction for a standard square edged orifice is 0·62, but with a rounded orifice it may have any value between 0·62 and 1·00, depending upon the degree of rounding. The coefficient of discharge for square edged orifices has a mean value of 0·61; this is increased with rounded edges and may have any value between 0·61 and 1·00, although it is not probable that values greater than 0·95 can be obtained except by the most careful adjustment of the rounded edges to the exact curve of a completely contracted jet. A rounded interior orifice is therefore always a source of error, when the object of the orifice is the measurement of the discharge.

Gauging water.—In gauging, the waste-board must have a thin edge. The height must be measured from the top of the sill, or waste-board, to the level of the surface where it is not affected by the overfall. The waste-board must have a free overfall.

Let H = Height of surface of water above sill in feet.
" h = Height of surface above sill in inches.
" V = Velocity of water approaching the sill in feet *per second*.
" C = Cubic feet discharged over each foot width of the sill *per minute*.

Then, if the stream above the sill is not in motion,

$$C = 214 \times \sqrt{H^3}, \quad \text{or } C = 5·15 \times \sqrt{h^3}.$$

If the stream is in motion,

$$C = 214 \times \sqrt{H^3 + .035\, V^2\, H^2}.$$

TABLE OF DISCHARGE FROM EACH FOOT OF WIDTH OF SILL, IN CUBIC FEET, PER MINUTE. (MOLESWORTH.)

Dept of sill.	Decimals of an Inch.									
	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
in.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.
0	0·0	·162	·46	·846	1·30	1·823	2·34	3·02	3·68	4·4
1	5·15	5·92	6·75	7·62	8·55	9·42	10·4	11·38	12·41	13·49
2	14·57	15·65	16·79	17·97	19·16	20·34	21·58	22·87	24·1	25·44
3	26·78	28·12	29·56	30·9	32·14	33·78	35·28	36·77	38·16	39·55
4	41·2	42·74	44·29	45·78	47·48	49·13	50·73	52·53	54·07	55·62
5	57·58	59·17	60·92	62·83	64·53	66·33	68·29	70·04	71·89	73·9
6	75·70	77·56	79·46	81·42	83·38	85·23	87·24	89·35	91·26	93·26
7	95·38	97·44	99·54	101·6	103·6	105·8	107·9	109·9	112·1	114·3
8	116·5	118·6	120·9	123·1	125·4	127·6	129·8	133·0	134·4	136·7
9	139	141·3	143·9	146	148·4	150·7	153·2	155·5	157·9	160·4
10	162·8	165·3	167·7	170·2	172·7	175·2	177·7	180·2	182·8	185·3
11	187·9	190·4	193	195·6	198·2	200·8	203·4	206·1	208·7	211·4
12	214·1	216·7	219·4	222·1	224·8	227·5	230·3	233	235·8	238·5

Depth of sill.	Decimals of a Foot.									
	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
feet.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.
0	0	6·7	19	34	53	75	99	125	153	183
1	214	246	280	317	357	391	432	472	515	560
2	605	650	697	746	796	845	896	950	1001	1057
3	1112	1168	1228	1284	1335	1401	1465	1527	1585	1643
4	1712	1776	1840	1902	1973	2041	2107	2182	2247	2311
5	2392	2458	2531	2610	2681	2756	2838	2910	2987	3070
6	3145	3222	3302	3383	3464	3541	3625	3712	3792	3875
7	3963	4049	4132	4220	4305	4395	4483	4569	4658	4751
8	4843	4930	5022	5116	5210	5303	5397	5489	5583	5682
9	5778	5872	5970	6067	6165	6264	6364	6463	6563	6664

DELIVERY OF WATER THROUGH PIPES.

The term *Head*, as applied to flowage of water through pipes, means the vertical distance from the surface of the water in the reservoir to the center of the orifice of the pipe at the point where the water is discharged. The *Head* should always be taken as the vertical distance between the lowest level of the water in the reservoir and the discharge orifice of the pipe.

Eytelwein's formula for the delivery of water in pipes:

D = Diameter of pipe in inches.
H = Head of water in feet.
L = Length of pipe in feet.
W = Cubic feet of water discharged per minute.

$$W = 4{\cdot}71 \times \sqrt{\frac{D^5 H}{L}}. \qquad D = 0{\cdot}538 \sqrt[5]{\frac{L \times W^2}{H}}.$$

Hawksley's formula.

G = Number of gallons delivered per hour.
L = Length of pipe in yards.
H = Head of water in feet.
D = Diameter of pipe in inches.

$$D = \tfrac{1}{15} \times \sqrt[5]{\frac{G^2 L}{H}}. \qquad G = \sqrt{\frac{(15D^2) \times H}{L}}.$$

Neville's general formula.

v = Velocity in feet per second.
r = Hydraulic mean depth in feet.
s = The sine of the inclination, or the total fall divided by the total length.

$$v = 140\sqrt{rs} - 11\sqrt[3]{rs}$$

In cylindrical pipes, v multiplied by $47{\cdot}124d^2$ gives the discharge per minute in cubic feet, or v multiplied by $293{\cdot}7286d^2$ gives the discharge per minute in gallons; d being the diameter of the pipe *in feet.*

COMPARISON OF FORMULÆ.

R = Mean hydraulic depth in feet = Area ÷ wet perimeter = $\frac{d}{4}$ for circular section of pipe.

S = Sine of slope = $\frac{H}{L}$.

v = Velocity in feet per second.
d = Diameter of pipe in feet.
L = Length of pipe in feet.
H = Head of water in feet.

Prony $v = 97{\cdot}05\sqrt{RS} - 0{\cdot}08$;

or $v = 99.88\sqrt{RS} - {\cdot}154$.

Eytelwein $v = 50\sqrt{\dfrac{dH}{L + 50d}}$;

" $v = 108\sqrt{RS} - 0{\cdot}13$.

Hawksley $v = 48\sqrt{\dfrac{dH}{L + 54d}}$.

Neville $v = 140\sqrt{RS} - 11\sqrt[3]{RS}$

Darcy $v = C\sqrt{RS}$; for value of C, see table.

Diam. of pipe, ins..	½	1	2	3	4	5	6	7	8
Value of C........	65	80	93	99	102	103	105	106	107
Diam. of pipe.....	9	10	12	14	16	18	20	22	24
Value of C.........	108	109	109·5	110	110·5	110·7	111	111·5	111·5

Maximum value of C for very large pipes, 113·3.

Kutter $v = C\sqrt{RS}$; where

$$C = \frac{181 + \frac{{\cdot}00281}{S}}{1 + \frac{{\cdot}026}{\sqrt{d}}\left(41{\cdot}6 + \frac{{\cdot}00281}{S}\right)}.$$

Weisbach $h = \dfrac{L}{r}\left({\cdot}0036 + \dfrac{{\cdot}0043}{\sqrt{v}}\right)\dfrac{v^2}{2g}$;

where h = head necessary to overcome the friction in a pipe, and r = the mean radius of the pipe in feet; g = gravity = 32·2.

Darcy $h = \dfrac{{\cdot}02\,L}{d}\left(1 + \dfrac{1}{12\,d}\right)\dfrac{v^2}{29}$.

TABLE SHOWING THE VELOCITY IN FEET PER SECOND, AND THE SUPPLY IN GALLONS PER MINUTE, FOR LONG PIPES FLOWING FULL CALCULATED FROM NEVILLE'S FORMULA. (Calculated by J. T. HURST.)

For greater diameters than those given in the table, divide the proposed diameter by 4, and *twice* the velocity opposite to the quotient in the table will be the required velocity; or the corresponding supply multiplied by 32 will be the approximate supply in gallons per minute.

Diameter of Pipe in inches.	Head of Water divided by Length of Pipe.								Diameter of Pipe in inches.
	$\frac{1}{1000}$		$\frac{2}{1000}$		$\frac{3}{1000}$		$\frac{4}{1000}$		
	Velocity in feet per second.	Supply in gallons per minute.	Velocity in feet per second.	Supply in gallons per minute.	Velocity in feet per second.	Supply in gallons per minute.	Velocity in feet per second.	Supply in galls. per minute.	
¼	·173	·05	·278	·08	·363	·10	·436	·13	¼
⅜	·212	·11	·336	·17	·436	·22	·522	·27	⅜
½	·278	·32	·436	·50	·562	·64	·670	·77	½
1	·336	·69	·522	1·07	·670	1·37	·798	1·63	1
1¼	·388	1·24	·600	1·91	·770	2·45	·911	2·90	1¼
1½	·436	2·00	·670	3·08	·856	3·93	1·02	4·67	1½
1¾	·481	3·00	·736	4·60	·938	5·86	1·11	6·94	1¾
2	·522	4·26	·798	6·51	1·02	8·29	1·20	9·81	2
2½	·600	7·64	·911	11·62	1·16	14·76	1·37	17·45	2½
3	·670	12·30	1·02	18·66	1·29	23·64	1·52	27·92	3
4	·798	26·03	1·20	39·23	1·52	49·63	1·79	58·53	4
5	·911	46·48	1·37	69·79	1·73	88·14	2·04	103·84	5
6	1·02	74·64	1·52	111·66	1·92	140·83	2·26	165·77	6
7	1·11	111·09	1·66	166·07	2·09	209·22	2·46	246·10	7
8	1·20	156·92	1·79	234·11	2·26	294·70	2·65	346·45	8
9	1·29	212·71	1·92	316·87	2·41	398·58	2·83	468·35	9
10	1·37	279·16	2·04	415·34	2·56	522·08	3·01	613·22	10
11	1·45	356·95	2·15	530·42	2·70	666·39	3·17	782·42	11
12	1·52	446·66	2·26	663·07	2·83	832·63	3·33	977·29	12
15	1·73	793·27	2·56	1174·7	3·21	1473·2	3·76	1727·8	15
18	1·92	1267·5	2·83	1873·4	3·55	2347·2	4·16	2751·4	18
24	2·26	2652·2	3·33	3909·2	4·16	4891·4	4·88	5727·8	24
30	2·56	4698·8	3·76	6911·3	4·71	8638·9	5·51	10109·7	30

Diameter of Pipe in inches.	Head of Water divided by Length of Pipe.								Diameter of Pipe in inches.
	$\frac{5}{1000}$		$\frac{6}{1000}$		$\frac{7}{1000}$		$\frac{8}{1000}$		
	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	
¼	·502	·14	·562	·16	·618	·18	·670	·19	¼
⅜	·600	·31	·670	·34	·736	·38	·798	·41	⅜
½	·770	88	·856	·98	·938	1·08	1·02	1·17	½
1	·911	1·86	1·02	2·08	1·11	2·27	1·20	2·45	1
1¼	1·04	3·31	1·16	3·69	1·27	4·04	1·37	4·36	1¼
1½	1·16	5·44	1·29	5·91	1·41	6·46	1·52	6·98	1½
1¾	1·27	7·91	1·41	8·79	1·55	9·68	1·66	10·38	1¾
2	1·37	11·17	1·52	12·41	1·66	13·56	1·79	14·63	2
2½	1·56	19·85	1·73	22·04	1·82	23·30	2·04	25·96	2½
3	1·73	31·73	1·92	35·21	2·09	38·43	2·26	41·44	3
4	2·04	66·46	2·26	73·68	2·46	80·36	2·65	86·61	4
5	2·31	117·80	2·56	130·52	2·79	142·30	3·01	153·31	5
6	2·56	187·95	2·83	208·16	3·09	226·84	3·33	244·32	6
7	2·79	278·90	3·09	308·76	3·37	335·60	3·62	362·21	7
8	3·01	392·46	3·33	434·35	3·62	473·09	3·90	509·38	8
9	3·21	530·36	3·55	586·82	3·87	639·02	4·16	687·85	9
10	3·40	694·24	3·76	767·92	4·09	833·58	4·41	899·75	10
11	3·59	885·56	3·97	979·39	4·32	1066·1	4·65	1147·2	11
12	3·76	1105·8	4·16	1222·9	4·53	1331·8	4·88	1432·0	12
15	4·26	1956·7	4·71	2159·7	5·12	2349·8	5·51	2527·4	15
18	4·71	3110·0	5·18	3426·1	5·65	3737·0	6·08	4019·3	18
24	5·51	6470·3	6·08	7145·4	6·61	7769·1	7·11	8351·6	24
30	6·22	11415·0	6·86	12601·3	7·50	13772·4	8·02	14720·4	30

Diameter of Pipe in inches.	Head of Water divided by Length of Pipe.								Diameter of Pipe in inches.
	9/1000		1/100		2/100		3/100		
	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	
3/8	·720	·21	·770	·22	1·16	·33	1·47	·42	3/8
1/2	·856	·44	·911	·46	1·37	·70	1·73	·88	1/2
3/4	1·09	1·24	1·16	1·33	1·73	1·98	2·18	2·50	3/4
1	1·29	2·63	1·37	2·79	2·04	4·15	2·56	5·22	1
1¼	1·47	4·67	1·56	4·96	2·31	7·36	2·90	9·24	1¼
1½	1·63	7·47	1·73	7·93	2·56	11·75	3·21	14·73	1½
1¾	1·78	11·10	1·89	11·79	2·79	17·43	3·50	21·84	1¾
2	1·92	15·65	2·04	16·61	3·01	24·53	3·76	30·72	2
2½	2·18	27·75	2·31	29·45	3·40	43·39	4·26	54·35	2½
3	2·41	44·29	2·56	46·99	3·76	69·11	4·71	86·39	3
4	2·83	92·51	3·01	98·60	4·41	144·20	5·51	179·73	4
5	3·21	163·69	3·40	173·70	4·99	254·50	6·22	317·08	5
6	3·55	260·81	3·76	277·10	5·51	404·30	6·86	504·05	6
7	3·87	386·57	4·09	408·45	5·99	598·62	7·50	749·83	7
8	4·16	543·49	4·41	575·83	6·44	840·68	8·02	1046·8	8
9	4·44	733·83	4·71	777·50	6·86	1134·1	8·54	1411·6	9
10	4·71	959·88	4·99	1016·9	7·27	1482·3	9·04	1844·3	10
11	4·96	1223·7	5·26	1298·4	7·65	1888·3	9·52	2348·8	11
12	5·18	1522·7	5·51	1617·6	8·02	2355·3	9·97	2928·7	12
15	5·87	2694·9	6·22	2853·8	9·04	4149·7	11·24	5157·0	15
18	6·48	4284·7	6·86	4536·5	10·07	6653·8	12·38	8184·8	18
24	7·58	8900·4	8·02	9421·1	11·63	13664·4	14·43	16958·3	24
30	8·54	15684·5	9·04	16599·0	13·10	23998·0	16·25	29828·1	30

Diameter of Pipe in inches.	Head of Water divided by Length of Pipe.								Diameter of Pipe in inches.
	4/100		5/100		6/100		7/100		
	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	
3/8	1·73	·50	1·96	·56	2·18	·62	2·37	·68	3/8
1/2	2·04	1·04	2·31	1·18	2·56	1·31	2·79	1·42	1/2
3/4	2·56	2·94	2·90	3·33	3·21	3·68	3·50	4·01	3/4
1	3·01	6·13	3·40	6·94	3·76	7·68	4·09	8·34	1
1¼	3·40	10·85	3·85	12·27	4·26	13·59	4·63	14·77	1¼
1½	3·76	17·28	4·26	19·57	4·71	21·60	5·12	23·50	1½
1¾	4·09	25·53	4·63	28·95	5·12	31·98	5·57	34·79	1¾
2	4·41	35·99	4·99	40·67	5·51	44·93	5·99	48·87	2
2½	4·99	63·55	5·63	71·79	6·22	79·27	6·76	86·18	2½
3	5·51	101·10	6·22	114·15	6·86	126·01	7·50	137·72	3
4	6·44	210·17	7·27	237·17	8·02	261·70	8·71	284·34	4
5	7·27	370·57	8·20	418·02	9·04	461·08	9·82	500·86	5
6	8·02	588·82	9·04	663·96	9·97	732·18	10·83	795·20	6
7	8·71	870·78	9·82	981·68	10·83	1082·4	11·76	1175·3	7
8	9·36	1222·0	10·55	1377·3	11·63	1518·3	12·63	1648·4	8
9	9·97	1647·4	11·24	1856·4	12·38	2046·2	13·44	2221·3	9
10	10·55	2152·0	11·89	2424·5	13·10	2665·9	14·22	2900·4	10
11	11·10	2740·1	12·49	3082·9	13·78	3401·4	14·96	3691·7	11
12	11·63	3416·1	13·10	3838·9	14·43	4239·6	15·66	4601·1	12
15	13·10	5998·2	14·75	6769·5	16·25	7457·0	17·63	8091·3	15
18	14·43	9539·1	16·25	10738·1	17·89	11826·3	19·41	12830·1	18
24	16·81	19754·1	18·92	22228·8	20·83	24474·3	22·59	26545·4	24
30	18·92	34732·5	21·28	39073·2	23·43	43011·1	25·41	46642·4	30

Diameter of Pipe in inches.	Head of Water divided by Length of Pipe.								Diameter of Pipe in inches.
	8/100		9/100		1/10		2/10		
	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	
⅜	2·56	·73	2·74	·79	2·90	·83	4.26	1·22	⅜
½	3·01	1·53	3·21	1·64	3·40	1·86	4·99	2·54	½
¾	3·76	4·32	4·01	4·60	4·26	4·89	6·22	7·13	¾
1	4·41	9·00	4·71	9·60	4·99	10·17	7·27	14·82	1
1¼	4·99	15·89	5·32	16·94	5·63	17·95	8·20	26·13	1¼
1½	5·51	25·27	5·87	26·95	6·22	28·54	9·04	41·50	1½
1¾	5·99	37·41	6·38	39·89	6·76	42·23	9·82	61·85	1¾
2	6·44	52·54	6·86	56·01	7·27	59·29	10·55	86·08	2
2½	7·27	92·64	7·74	98·73	8·20	104·50	11·89	151·53	2½
3	8·02	147·20	8·54	156·85	9·04	165·99	13·10	239·93	3
4	9·36	305·50	9·97	325·41	10·55	344·32	15·26	498·17	4
5	10·55	537·99	11·24	572·99	11·89	606·13	17·18	876·11	5
6	11·63	854·02	12·38	909·42	13·10	959·72	18·92	1389·8	6
7	12·63	1262·1	13·44	1343·7	14·22	1421·2	20·52	2051·3	7
8	13·56	1765·8	14·43	1884·3	15·26	1992·7	22·02	2874·7	8
9	14·43	2384·8	15·36	2538·6	16·25	2684·5	23·43	3871·0	9
10	15·26	3118·5	16·25	3314·2	17·18	3504·5	24·76	5051·3	10
11	16·06	3962·7	17·09	4217·9	18·07	4459·7	26·04	6425·9	11
12	16·81	4938·6	17·89	5256·2	18·92	5557·2	27·25	8004·7	12
15	18·92	8688·1	20·13	9240·3	21·28	9768·3	30·63	14059·7	15
18	20·83	13766·8	22·16	14648·5	23·43	15484·0	33·70	22278·1	18
24	24·24	28477·6	25·79	30296·3	27·25	32018·8	39·17	46016·9	24
30	27·25	50029·4	28·99	53218·5	30·63	56238·9	44·0	80770·7	30

Diameter of Pipe in inches.	Head of Water divided by Length of Pipe.								Diameter of Pipe in inches.
	3/10		4/10		5/10		6/10		
	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	
⅜	5·32	1·52	6·22	1·78	7·02	2·01	7·74	2·22	⅜
½	6·22	3·17	7·27	3·71	8·20	4·18	9·04	4·61	½
¾	7·74	8·89	9·04	10·37	10·19	11·69	11·24	12·89	¾
1	9·04	18·44	10·55	21·52	11·89	24·25	13·10	26·66	1
1¼	10·19	32·48	11·89	37·88	13·39	42·67	14·75	47·01	1¼
1½	11·24	51·57	13·10	59·98	14·75	67·70	16·25	74·57	1½
1¾	12·20	76·21	14·22	88·82	16·01	99·99	17·63	110·14	1¾
2	13·10	106·64	15·26	124·54	17·18	140·18	18·92	154·37	2
2½	14·75	188·42	17·18	219·03	19·33	246·46	21·28	271·34	2½
3	16·25	298·28	18·92	347·32	21·28	390·73	23·43	430·11	3
4	18·92	617·47	22·02	718·66	24·76	808·21	25·25	824·14	4
5	21·28	1085·4	24·76	1262·8	27·84	1419·8	30·63	1561·7	5
6	23·43	1720·4	27·25	2001·2	30·63	2248·9	33·70	2474·8	6
7	25·41	2539·4	29·55	2953·2	33·21	3319·2	36·53	3651·1	7
8	27·25	3557·6	31·67	4134·9	35·60	4647·9	39·17	5113·0	8
9	28·99	4789·7	33·70	5568·3	37·87	6256·8	41·65	6881·1	9
10	30·63	6246·9	35·60	7262·3	40·01	8161·0	44·00	8974·3	10
11	32·20	7947·9	37·41	9234·4	42·00	10365·4	46·24	11411·6	11
12	33·70	9899·2	39·17	11504·2	44·00	12923·0	48·38	14209·8	12
15	37·87	17380·0	44·00	20192·7	49·42	22679·2	54·33	24932·9	15
18	41·65	27524·2	48·38	31972·0	54·33	35903·4	59·72	39465·9	18
24	48·38	56839·1	56·18	66005·2	63·07	74102·4	69·32	81442·6	24
30	54·53	99731·6	63·07	115785	70·80	129971	77·80	142825	30

Diameter of Pipe in Inches.	Head of Water divided by Length of Pipe.								Diameter of Pipe in Inches.
	$\frac{7}{10}$		$\frac{8}{10}$		$\frac{9}{10}$		1		
	Vel'city in feet per second.	Supply in gallons per minute.	Vel'city in feet per second.	Supply in gallons per minute.	Vel'city in feet per second.	Supply in gallons per minute.	Vel'city in feet per second.	Supply in gallons per minute.	
⅜	8·42	2·41	9.04	2.59	9·63	2·76	10·19	2·92	⅜
½	9·82	5·01	10·55	5·38	11·24	5·73	11·89	6·06	½
¾	12·20	14·00	13·10	15·00	13·93	15·98	14·75	16·92	¾
1	14·22	29·00	15·26	31·14	16·25	33·14	17·18	35·04	1
1¼	16·01	51·02	17·18	54·76	18·28	58·28	19·33	61·61	1¼
1½	17·63	80·91	18·92	86·83	20·13	92·40	21·28	97·68	1½
1¾	19·13	119·48	20·52	128·21	21·84	136·42	23·08	144·20	1¾
2	20·52	167·45	22·02	179·67	23·43	191·16	24·76	202·05	2
2½	23·08	294·29	24·76	315·71	26·34	335·86	27·84	354·95	2½
3	25·41	466·42	27·25	500·29	28 99	532·18	30·63	562·22	3
4	29·55	964·31	31·67	1033·7	33·70	1099·9	35·60	1162·0	4
5	33·21	1692·6	35·60	1815·6	37·87	1931·1	40·01	2040·2	5
6	36·53	2682·4	39·17	2876·1	41·65	3058·2	44·00	3230·8	6
7	39·59	3957·0	42·44	4242·3	45·13	4510·7	47·67	4764·9	7
8	42·44	5540·9	45·50	5940·0	48·38	6315·4	51·10	6671·1	8
9	45·13	7456·4	48·38	7993·0	51·44	8499·2	54·33	8975·8	9
10	47·67	9724·4	51·10	10423·5	54·33	11081·3	57·38	11704·2	10
11	50·10	12364·4	53·70	13252·8	57·08	14088·5	60·29	14840·0	11
12	52·40	15391·1	56·18	16501·3	59·72	17540·4	63·07	18525·6	12
15	58·85	27009·8	63·07	28946·2	67·04	30767·7	70·80	32492·7	15
18	64·52	42641·5	69·32	45811·5	73·67	48690·4	77·80	51416·9	18
24	75·07	88204·4	80·44	94508·9	85·49	100438·1	90·26	106052·8	24
30	84·25	154668	90·26	165708	95·92	176090	101·26	185902	30

FRICTION OF KNEES AND BENDS.

A = Angle of bend or knee with forward line of direction.
V = Velocity of water in feet per second.
R = Radius of centre line of bend.
r = Radius of bore of pipe (or ½ diameter).
K = Coefficient for angles of knees.
L = Coefficient for curvature of bends.
H = Head of water in feet necessary to overcome the friction of the bend or knee.

or knees, $H = \cdot 0155\ V^2\ K$.
The value of K is as follows for different angles:

A° =	20°	40°	60°	80°	90°	100°	120°
K =	·046	·139	·364	·74	·98	1·26	1·86

For bends, $H = \cdot 0155\ V^2 \left(\frac{A}{180} L \right)$.

Values of L with various ratios of the radius of bend to radius of bore:

When $\frac{r}{R}$ =	·1	·2	·3	·4	·5	·6	·7	·8	·9	1·0
In circular section L	·131	·138	·158	·206	·294	·44	·66	·98	1·4	2·0
In rectangular L	·124	·135	·18	·25	·4	·64	1·01	1·55	2·3	3·2

PUMPING ENGINES.

G = Number of gallons to be raised in 24 hours.
F = Number of cube feet raised in 24 hours.
h = Height in feet to which the water is to be raised.
H P = Actual horse-power required.

$$H P = \frac{G \times h}{4752000} \text{ or } \frac{F \times h}{762088}.$$

20 per cent. must be added to overcome a friction, etc., and 50 or 60 per cent. more is usually allowed for contingencies, making a total of 70 or 80 per cent. additional power.

TO FIND THE DIAMETER OF A SINGLE-ACTING PUMP.

L = Length of stroke in feet.
G = Number of gallons to be delivered per minute.
F = Number of cubic feet to be delivered per minute.
N = Number of strokes per minute.
D = Diameter of pump in inches.
$F = \cdot00545\ D^2\ L\ N.$
$G = \cdot034\ D^2\ L\ N.$

$$D = \sqrt{\frac{G}{\cdot034\ L\ N}}$$

$$D = \sqrt{\frac{F}{\cdot00545\ L\ N}}$$

Note.—These formulæ give the net diameter of the pump-plunger; it is usual to increase the area of the plunger ¼th, to allow for leakage, etc.

USEFUL NUMBERS FOR PUMPS.

D = Diameter of pump in inches.
S = Stroke of pump in inches.
$D.^2\ S \times \cdot7854$ = cubic inches.
$D.^2\ S \times \cdot002833$ = gallons.
$D.^2\ S \times \cdot0004545$ = cubic feet.
$D.^2\ S \times \cdot02833$ = lbs. fresh water.

THE TRANSMISSION OF POWER BY THE USE OF COMPRESSED AIR.

By E. Hill, of Norwalk Iron Works Co.

The increasing use which is being made of compressed air engines, for mine and underground work, stimulates the inquiry regarding their efficiency. By the term efficiency, we mean the percentage which the power given out by the air engine bears to the power required to compress the air in the compressor.

The situation is apparently very simple. An engine drives an air compressor which forces air into a reservoir. The air under pressure is led through pipes to the air engine and is there used after the manner of steam.

The resulting power is frequently a small percentage of the power expended. In a large number of cases the losses are due to poor designing, and are not chargeable as faults of the system or even to poor workmanship.

The losses are chargeable, first to friction of the compressor. This will amount ordinarily to 15 or 20 per cent., and can be helped by good workmanship, but cannot probably be reduced below 10 per c nt. Second, we have the loss occasioned by pumping the air of the engine room, rather than air drawn from a cooler place. This loss varies with the season and amounts to from 8 to 10 per cent. This can all be saved. The third loss or series of losses arises in the compressing cylinder. Insufficient supply, difficult discharge, defective cooling arrangements, poor lubrication, and a host of other causes, perplex the designer and rob the owner of power. The fourth loss is found in the pipe. This has heretofore received by no means the consideration which the subject demands. The loss varies with every different situation, and is subject to somewhat complex influences. The fifth loss is chargeable to fall of temperature in the cylinder of the air engine. Losses arising from leaks are often serious, but the remedy is too evident to require demonstration. No leak can be too small to require immediate attention. An attendant who is careless about packings and hose couplings will permit losses for which no amount of engineering skill can compensate.

We can only realize 100 per cent. efficiency in the air engine, leaving friction out of our consideration, when the expansion of the air and the changes of its temperature in the expanding or air engine cylinder are precisely the reverse of the changes which have taken place during the compression of the air in the compressing cylinder. But these conditions can never be realized. The air during compression becomes heated, and during expansion it becomes cold. If the air immediately after compression, before the loss of any heat, was used in

an air engine and there perfectly expanded back to atmospheric pressure, it would on being exhausted have the same temperature it had before compression and its efficiency would be 100 per cent.

But the loss of heat after compression and before use cannot be prevented, as the air is exposed to such very large radiating surfaces in the reservoir and pipes, on its passage to the air engine. The heat, which escapes in this way, did, while in the compressing cylinder, add much to the resistance of the air to compression, and since it is sure to escape, at some time, either in reservoir or pipes, it is evidently the best plan to remove it as fast as possible from the cylinder and thus remove one element of resistance. Hence we find compressors are almost universally provided with cooling attachments more or less perfect in their action, the aim being to secure isothermal compression, or compression having equal temperature throughout. Where the temperature rises, without check, during compression, the term adiabatic compression is employed.

If air compressed isothermally is used with perfect expansion and the fall of temperature during expansion be prevented, then we will have 100 per cent. efficiency. But air will grow cold on being expanded in an engine and hence we conclude that warming attachments have the same economic place on an air engine, that cooling attachments have on an air compressor. In fact we find attachments of this kind, more particularly in large and permanently located engines, but for practical reasons their use on the most of engines for mine work is dispensed with, and the engines expand the air adiabatically, or without receiving heat.

The practical engineer therefore has to deal with nearly isothermal compression, and nearly adiabatic expansion, and must also consider that the air in reservoirs and pipes becomes of the same temperature as surrounding objects. Consideration must also be had for the friction of the compressor and the air engine. We find for the ordinary pressures, about 60 pounds which are most commonly used, that the decrease in resistance to compression, which is secured by the cooling attachments, is almost exactly equaled by the friction of the compressor. Hence it is safe in calculating the efficiency of the air engine, to consider the compressor as being without cooling attachments and also as working without friction. The results of such calculations will be too high efficiencies for light pressures, which are little used,—about correct for medium pressures which are commonly employed, and too low for higher pressures, and will thus have the advantage of not being over estimated. This result is occasioned by the fact, that owing to the slight heat in compressing low pressures of air the saving of power by the cooling attachments is not equal to the friction of the machine, but at high pressures on account of the great heat the cooling attachments are of great value and save very much more power than friction consumes.

In the expanding engines, the expansion never falls as low as the adiabatic law would indicate, owing to a number of reasons, but we will consider the expansion as being adiabatic, as an error in calculations caused thereby will be on the "safe side" and the actual power will exceed the calculated. We therefore consider the compressor and engine as following the adiabatic law of compression and expansion and as working without friction.

With this view of the case, the efficiency of an air engine, working with perfect expansion, stated in percentages of the power required to operate the compressor, can be placed as below for the various pressures above the atmosphere.

Pressure above	the	atmosphere,		2·9 lbs.	94·85	per	cent.	efficiency.
"	"	"	"	14·7 "	81·79	"	"	"
"	"	"	"	29·4 "	72·72	"	"	"
"	"	"	"	44·1 "	66·90	"	"	"
"	"	"	"	58·8 "	62·70	"	"	"
"	"	"	"	73·5 "	59·48	"	"	"
"	"	"	"	88·2 "	56·88	"	"	"

We observe that the efficiencies for the lower pressures are very much greater than for the high pressures, and the conclusion is almost irresistible that to secure economical results, we must design our air engines to run with light pressures. And in fact, the consideration of tables similar to the above, heretofore published by writers on this subject, has led many engineers into grave errors.

The pipe has been entirely neglected. We notice that a pressure of 2·9 lbs. is credited with an efficiency of 94·85 per cent. It is clear that if the air was conveyed through a pipe, and the length of the pipe and the velocity of flow were such that 2·9 lbs. pressure was lost in friction then its efficiency instead of being 94·85 per cent. would be absolutely zero. It is therefore the power, which we can get from the air after it has passed the pipe and lost a part of its pressure by friction, that we must consider, when we state the efficiency of our entire apparatus.

Our table of efficiencies with a loss of 2·9 lbs. in the pipe, now gives us different values for the efficiencies at the various pressures.

Pressure above the atmosphere,	2·9 lbs.	00·00 per cent. efficiency.
" " " "	14·7 "	70·44 " " "
" " " "	29·4 "	68·81 " " "
" " " "	44·1 "	64·87 " " "
" " " "	58·8 "	61·48 " " "
" " " "	73·5 "	58·62 " " "
" " " "	88·2 "	56·23 " " "

It will be noticed that the light pressures have lost most by the pipe friction; 2·9 lbs. having lost 100 per cent.; 14·7. lbs. 11 per cent. and 88·2 lbs. only a trifle over one-half of one per cent. We see that now 14·7 lbs. is apparently the economical pressure to use. But a further careful analysis of the subject shows, that when the loss in the pipe is 2·9 lbs., then 20·5 lbs. is the most economical pressure to use and that the efficiency is 71 per cent. But 2·9 lbs. is a very small loss between compressor and air engine, and cases are extremely exceptional where the friction of valves, pipes, elbows, ports, etc., does not far exceed this. Yet, with these conditions, which are very difficult to fill, we see that 20·5 lbs. is the lightest pressure which should probably ever be used for conveying power, and that 71 per cent. is an efficiency scarcely to be obtained.

Continuing our investigation and taking examples where the pipe friction amounts to 5·8 lbs., we find the following efficiencies to correspond to the stated pressure:

Pressure above the atmosphere,	14·7 lbs.	57·14 per cent. efficiency.
" " " "	29·4 "	64·49 " " "
" " " "	44·1 "	62·71 " " "
" " " "	58·8 "	60·12 " " "
" " " "	73·5 "	57·73 " " "
" " " "	88·2 "	55·59 " " "

We again notice that as friction increases, or in other words, when we begin to use more air and make greater demands on the carrying capacity of the pipe, then we must increase pressure very considerably to attain the most economical results. If the demands are such as to increase the friction and loss in pipe, to 14·7 lbs., the air of 14·7 lbs. pressure at the compressor is entirely useless at the air engine.

The table will stand thus:

Pressure above the atmosphere,	14·7 lbs.	00·00 per cent. efficiency.
" " " "	29·4 "	48·53 " " "
" " " "	44·1 "	55·18 " " "
" " " "	58·8 "	55·64 " " "
" " " "	73·5 "	54·74 " " "
" " " "	88·2 "	53·44 " " "

It is to be noticed that 88·2 lbs. pressure has lost only about 3½ per cent. of its efficiency by reason of as high a friction as 14·7 lbs. while the efficiency of the lower pressures has been greatly affected.

As the friction increases we see that the most efficient and consequently most economical pressure increases. In fact, for any given friction in a pipe the pressure at the compressor must not be carried below a certain limit. The following table gives the *lowest pressures* which should be used at the compressor with varying amounts of friction in the pipe:

2·9 lbs. friction.	20·5 lbs. at compressor.	70·92 efficiency.
5·8 " "	29·4 " "	64·49 "
8·8 " "	38·2 " "	60·64 "
11·7 " "	47· " "	57·87 "
14·7 " "	52·8 " "	55·73 "
17·6 " "	61·7 " "	53·98 "
20·5 " "	70·5 " "	52·52 "
23·5 " "	76·4 " "	51·26 "
26·4 " "	82·3 " "	50·17 "
29·4 " "	88·2 " "	49·19 "

So long as the friction of the pipe equals the amounts given above an efficiency greater than the corresponding sums stated in the table cannot be expected. If we should have a case which corresponded to any of these cited in the table, we could only increase efficiency by reducing the friction.

An increase in the size of pipe will reduce friction by reason of the lower velocity of flow required for the same amount of air. But many situations will not admit of large pipes being employed, owing to considerations of economy outside of the question of fuel or prime motor capacity.

An increase of pressure will decrease the bulk of air passing the pipe, and in that proportion will decrease its velocity. This will decrease the loss by friction, and, as far as that goes, we have a gain. But we subject ourselves to a new loss, and that is the diminishing efficiencies of increasing pressures. Yet as each cubic foot of air is at a higher pressure and therefore carries more power, we will not need as many cubic feet, as before, for the same work. It is obvious that, with so many sources of gain or loss, the question of selecting the proper pressure is not to be decided hastily.

As an illustration of the combined effect of these different elements we will suppose a very common case.

Compressor 102 revolutions, pressure 52·8 lbs., loss in pipe 14·7 lbs., machine in mine running at 38·2 lbs., efficiency 55·73.

So long as the friction of the pipe amounts to 14·7 lbs., we have seen that 52·8 lbs. is the best pressure and 55·78 the greatest efficiency. We will reduce the friction by reducing the bulk of air passing through the pipe. We reduce the cylinder of the air engine so that it requires 47 lbs. pressure to do the same work as before. We find now the friction of pipe drops to 11·7 lbs. The pressure on the compressor rises to 58·8 lbs. its number of revolutions falls to 100 and the resulting efficiency is 57·22 per cent.

Another change of pressure on compressor to 64·7 lbs. would decrease its revolutions to 93, friction to 8·8 lbs., and efficiency would rise to 57·94 per cent. Still again increasing pressure to 73·5 lbs. we have only 84 revolutions of compressor, 5·8 lbs. loss in pipe and efficiency of 57·73 per cent. In this last case the efficiency begins to fall off a little, and higher pressures would now show less efficiency, but, in comparison with the first example, we find we are doing the same work in the mine with a trifle less power and with a decrease of nearly 20 per cent. in the speed of the compressor.

Other common examples can be shown where an increase of pressure would result in wonderful increase in efficiency and economy. There are many cases where light pressures and high velocity in the pipe will convey a given power with greater economy than higher air pressures and lower speed of flow through the pipe. But these cases arise mostly when the higher air pressures become very much greater than are at present in common use.

Therefore in estimating the efficiency of the complete outfit we find that the pipe and the pressure are very important elements and must be determined with care and skill to secure the most satisfactory results. As the volume and power of air varies with its pressure, the size and consequent cost of compressor for a certain work would also be affected by the pressure. To plan an outfit for a mine due regard must be had to cost of fuel or prime motor power, and also to cost of compressor, pipes and machinery, as the saving in one is often secured by a sacrifice in the other.

Next to determining the size of pipe, the skillful engineer has need of further care in the proper position of reservoirs, branches, drains and other attachments, as only by the exercise of good judgment in this can satisfactory working be secured.

FRICTION OF AIR IN PIPES.

Air in its passage through pipes is subject to friction in the same manner as water or any other fluid. The pressure at the compressor must be greater than at the point of consumption in order to overcome this resistance. The power which is needed to produce the extra pressure representing the friction of the pipe, is lost, as there can be no useful return for it. The friction is affected by very many circumstances, but chiefly to be noted, is the fact that it increases in direct proportion to the length of the pipe and also as the square of the velocity of the flow of air. The pressure of the air does not affect it.

The losses by friction may be quite serious if the piping system is poorly designed, and on the other hand extravagant expenditure in pipe may result from a timid overrating of the evils of friction. A thorough knowledge of the laws governing the whole matter, as well as a ripe experience, is necessary to secure true economy and mechanical success.

The loss of power in pipe friction is not always the most serious result. When a number of machines are in use in a mine and the pipes are so small as to cause a considerable loss of pressure by friction, then there will be sudden and violent fluctuations in pressure whenever a machine is started or stopped. Breakages will be of common occurrence as the changes are too quick to be entirely guarded against by the attendant. Perfectly even pressure at the compressor is no safeguard against this class of accidents. The trouble arises in the pipe and the remedy must be there applied. A system of reservoirs and governing valves will regulate these matters and allow successful work to be done with pipes which would otherwise be entirely inadmissible.

LOSS OF PRESSURE IN POUNDS PER SQUARE INCH, BY FLOW OF AIR IN PIPES.

CALCULATED FOR PIPES 1000 FEET LONG.

For other lengths the loss varies directly as the length.

Velocity of air at the entrance to the pipe.		ONE INCH PIPE.			TWO INCH PIPE.			TWO AND ONE-HALF INCH PIPE.		
Metres per second.	Feet per second.	Loss of pressure in lbs.	Cubic feet of free air passed per minute when compressed to 60 lbs. above the atmosphere.	Cubic feet of free air passed per minute when compressed to 80 lbs. above the atmosphere.	Loss of pressure in lbs.	Cubic feet of free air compressed to 60 lbs.	Cubic feet of free air compressed to 80 lbs.	Loss of pressure in lbs.	Cubic feet of free air compressed to 60 lbs.	Cubic feet of free air compressed to 80 lbs.
1	3·28	·1435	6·	7·	·0794	23·	29·	·0574	32·	41·
2	6·56	·6405	12·	15·	·3050	46·	59·	·2562	65·	82·
3	9·84	1·4545	18·	22·	·7216	69·	88·	·5818	97·	124·
4	13·12	2·5620	24·	29·	1·2566	93·	117·	1·0248	130·	165·
5	16·40	3·9845	29·	37·	1·9642	116·	146·	1·5738	163·	207·
6	19·68	5·4225	35·	44·	2·7120	139·	175·	2·1690	195·	247·
8	26·24	10·2480	47·	59·	5·0264	185·	234·	4·0992	260·	330·
10	32·80	15·7380	59·	74·	7·8568	232·	294·	6·2952	326·	413·
		THREE INCHES.			FOUR INCHES.			FIVE INCHES.		
1	3·28	·0463	48·	60·	·0347	86	109·	·0287	134·	169·
2	6·56	·2092	96·	121·	·1525	172·	217·	·1281	268·	239·
3	9·84	·4880	144·	182·	·3608	258·	326·	·2909	402·	509·
4	13·12	·8381	193·	243·	·6283	343·	436·	·5124	537·	678·
5	16·40	1·3176	241·	304·	·9821	429·	544·	·7869	671·	844·
6	19·68	1·8080	289·	364·	1·3560	515·	653·	1·0845	805·	1017·
8	26·24	3·3525	386·	486·	2·5132	687·	871·	2·0496	1073·	1357·
10	32·80	5·2704	480·	607·	3·9284	859·	1088·	3·1476	1342·	1696·
		SIX INCHES.			EIGHT INCHES.			TEN INCHES.		
1	3·28	·0232	193·	244·	·0173	343·	434·	·0143	537·	680·
2	6·56	·1046	386·	488·	·0762	687·	864·	·0640	1073·	1359·
3	9·84	·2440	579·	633·	·1805	1030·	1303·	·1455	1610·	2039·
4	13·12	·4190	772·	977·	·3141	1373·	1736·	·2562	2146·	2719·
5	16·40	·6588	965·	1221·	·4910	1717·	2171·	·3934	2683·	3399·
6	19·68	·9040	1158·	1466·	·6780	2060·	2605·	·5423	3220·	4079·
8	26·24	1·6762	1544·	1954·	1·2556	2747·	3473·	1·0248	4293·	5438·
10	32·80	2·6352	1931·	2443·	1·9642	3434·	4342·	1·5738	5367·	6798·

The resistance is not varied by the pressure, only so far as changes in pressure varies the velocity. It increases about as the square of the velocity, and directly as the length.

Elbows, short turns and leaks in pipes all tend to reduce the pressure in addition to the losses given in the table.

TABLE SHOWING LOSS BY FRICTION IN ELBOWS.

An elbow, with a radius of one-half the diameter of the pipe, is as short as can be made.

Radius of elbow			Equivalent length of straight pipe	
Radius of elbow	5 diameters.	Equivalent length of straight pipe	7·85	diametrse.
"	3	" " " " "	8·24	"
"	2	" " " " "	9·03	"
"	1½	" " " " "	10·36	"
"	1¼	" " " " "	12·72	"
"	1	" " " " "	17·51	"
"	¾	" " " " "	35·09	"
"	½	" " " " "	121·20	"

MINE SURVEYING.

Instruments.—The instruments necessary to make a mine survey are a transi or compass, chain or steel tape and pins, and a clinometer or slope level. Othe necessary tools are a hatchet and nails for marking stations, or any other tool that the surveyor may need to mark them according to his favorite plan, and 25 ft. or a 50 ft. metallic tape line.

THE COMPASS.

The compass may be either a pocket compass, or a surveyor's compass, an may be used by holding in the hand, or with a tripod. The Jacob's Staff, con venient for use on the surface, is frequently useless in the mine. The compass i not accurate enough for the construction of a general map of the mine. It i useful inasmuch as it enables the mine foreman to readily secure an *approximat* idea of the shape of his workings, and from a plan constructed by its use he ca get an *approximate* course on which to drive an opening designed to connec two or more given points. If the opening is one that will be expensive to drive and should be straight, the compass survey should never be relied on. Th Pocket-Compass consists merely of a magnetic needle swinging freely on a pivo in the centre, all enclosed in a metallic or wooden box with a glass face unde which is a circle graduated into 360 degrees. They are made both with folding sights and without. These folding sights are accurately placed at the North and South sides of the compass box, that on the North end being a slot in which is fixed a perpendicular wire, and that on the South end being merely a fine slot with several small circular holes along it, to which the eye is applied in sighting.

The Surveyor's Compass is similar to the Pocket Compass with folding sights, only larger. It is arranged for use on a tripod or a Jacob's Staff by having a spindle with a ball end, which fits accurately into a socket that may be screwed on to either the tripod or Jacob's Staff. It is also supplied with two level tubes set at right angles to each other. The ball and socket joint enables the compass box to be moved in any direction, so that it can readily be levelled. It is also arranged to swing horizontally on its axis, and it can be clamped in any position.

TO ADJUST THE COMPASS.

The levels.—First bring the bubbles into the centre, by the pressure of the hand on different parts of the plate, and then turn the compass half way around; should the bubbles run to the end of the tubes, it would indicate that those ends were the highest; lower them by tightening the screws immediately under, and loosening those under the lowest ends until, by estimation, the error is half removed; level the plate again, and repeat the first operation until the bubbles will remain in the centre, during an entire revolution of the compass.

The sights may next be tested by observing through the slits a fine hair or thread, made exactly vertical by a plumb. Should the hair appear on one side of the slit, the sight must be adjusted by filing off its under surface on that side which seems the highest.

The needle is adjusted in the following manner: Having the eye nearly in the same plane with the graduated rim of the compass circle, with a small splinter of wood or a slender iron wire, bring one end of the needle in line with any prominent division of the circle, as the zero, or ninety degree mark, and notice if the other end corresponds with the degree on the opposite side; if it does, the needle is said to "cut" opposite degrees; if not, bend the centre-pin by applying a small brass wrench, furnished with our compasses, about one-eighth of an inch below the point of the pin, until the ends of the needle are brought into line with the opposite degrees.

Then holding the needle in the same position, turn the compass half way around, and note whether it now cuts opposite degrees; if not correct half the error by bending the needle, and the remainder by bending the centre-pin.

The operation must be repeated until perfect reversion is secured in the first position.

This being obtained, it may be tried on another quarter of the circle; if any error is there manifested, the correction must be made in the centre-pin only, the needle being already straightened by the previous operation.

When again made to cut, it should be tried on the other quarters of the circle, and corrections made in the same manner until the error is entirely removed, and the needle will reverse in every point of the divided circle.

TO USE THE COMPASS.

In using the compass the surveyor should keep the South end towards his person and read the bearings from the North end of the needle. In the Surveyor's Compass he will observe that the position of the E and W letters on the face of the compass are reversed from their natural position, in order that the direction of the sight may be correctly read.

The compass circle being graduated to half degrees, a little practice will enable the surveyor to read the bearings to quarters—estimating with his eye the space bisected by the point of the needle.

The compass is usually divided into quadrants and zero is placed at the North and South ends. Ninety degrees is placed at the E and W marks, and the graduations run right and left from the zero marks to 90°. In reading the bearing, the surveyor will notice that if the sights are pointed in a N.W. direction the north end of the needle, which always points approximately North, is to the right of the front sight or front end of the telescope, and as the number of degrees is read from it, the letters marking the cardinal points of the compass read correctly. If the E or east mark was on the right side of the circle a N. W. course would read N. E. This same remark applies to all four quadrants. The compass should always be in a level position.

THE TRANSIT.

The transit is the only instrument that should be used for measuring angles in any survey where great accuracy is desired. The advantages of a transit over a vernier compass are mainly due to the use of a telescope. By its use angles can be measured either vertically or horizontally, and as the vernier is used throughout extreme accuracy is secured.

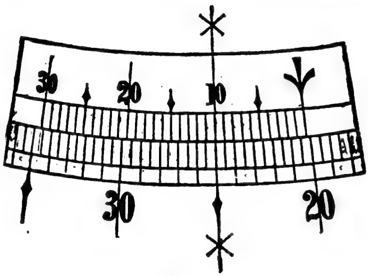


Fig. 2.

The verniers on a transit differ from those on a compass in detail only. The principle is the same. The transit vernier is so divided that 30 spaces on it equal in length 29 on the limb of the instrument. The method of reading it is practically the same as reading a compass vernier, except that on the transit the vernier is made with all of the 30 divisions on one side of the zero mark. (See *Fig. 2.*)

Each division is therefore $\frac{1}{30}$, or in other words 1 minute longer than the half degree graduations on the limb.

To read the vernier.—As the compass vernier is usually so made that there are but 15 spaces on each side of the zero mark it is read as follows: Note the degrees and half degrees on the limb of the instrument. If the space passed beyond the degree or half degree mark, by the zero mark on the vernier is less than $\frac{1}{2}$ the space of half a degree on the limb, the number of minutes is of course less than 15 and must be read from the lower row of figures. If the space passed is greater than one-half of the spacing on the limb, read the upper row of figures. The line on the vernier that exactly coincides with a line on the limb, is the mark that denotes the number of minutes. If the index is moved to the right, read the minutes from the left half of the vernier; if moved to the left, read the right side of the vernier.

To turn off the variation.—The surveyor having a vernier attached to his compass, can by moving the vernier to either side, and with it of course the compass circle attached, set the compass to any variation. Then by placing his instrument on some well defined line of the old survey, and by turning the tangent screw (slow motion screw) until the needle of his compass indicates the same bearing as that given in the old field notes of the original survey. Then by screwing up the clamping nut underneath the vernier, he can run all the other lines from the old field notes without further alteration.

The reading of the vernier on the limb gives the amount of variation since the original survey was made.

MAGNETIC VARIATION.

It is well known that the magnetic needle, in almost all parts of North America, points more or less to the east or west of a true line from North to South. This deviation, which is called the variation or declination of the needle, is notconstant, but increases or decreases to a very sensible amount in a series of years.

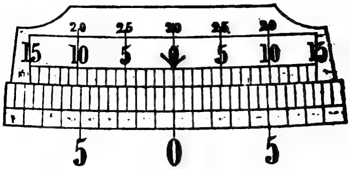


Fig. 1.

For this reason, in running over the lines of a tract of land, from field notes of some years' standing, the surveyor would be obliged to make an allowance, both perplexing and uncertain, in the bearing of every line. To avoid this difficulty the vernier was devised, the arrangement of which for compasses is usually as follows: The vernier is so graduated that 30 spaces on it equal 31 on the limb of the instrument. (See *Fig. 1.*)

In the above cut the reading is 20° 10′. If the zero on the vernier should be beyond 20½° on the limb of the transit, and the line marked 10 should coincide with a line on the limb, the reading would be 20° 40′. In case the 12th line from zero should coincide with a line on the limb, the reading would be 20° 42′, etc.

The interior of the telescope is fitted up with a diaphragm or cross wire ring to which cross wires are attached. These cross wires are either of platinum or are strands of spider web. They are set at right angles to each other and are so arranged that they can be adjusted so as to be exactly perpendicular and exactly horizontal. This diaphragm is suspended in the telescope by four capstan head screws, and can be moved in either direction by working the screws with an ordinary adjusting pin.

The intersection of the wires forms a very minute point, which, when they are adjusted, determines the optical axis of the telescope, and enables the surveyor to fix it upon an object with the greatest precision.

The imaginary line passing through the optical axis of the telescope, is termed the "line of collimation," and the operation of bringing the intersection of the wires into the optical axis, is called the "adjustment of the line of collimation." This will be hereafter described.

The openings in the telescope tube are made considerably larger than the screws, so that when these are loosened, the whole ring can be turned around for a short distance in either direction.

The object of this will be seen more plainly, when we describe the means by which the wire is made truly vertical.

TO ADJUST THE TRANSIT.

The levels of this instrument have a capstan head screw at each end, and are adjusted with a steel pin in the same manner as those of the Plain compass.

The needle is also adjusted as described in our account of that instrument.

Line of collimation.—To make this adjustment, which is, in other words, to bring the intersection of the wires into the optical axis of the telescope, so that the instrument, when placed in the middle of a straight line will, by the revolution of the telescope, cut its extremities—proceed as follows:

Set the instrument firmly on the ground and level it carefully; and then having brought the wires into the focus of the eye-piece, adjust the object-glass on some well defined point, as the edge of a chimney or other object, at a distance of from two to five hundred feet; determine if the vertical wire is plumb, by clamping the instrument firmly to the spindle and applying the wire to the vertical edge of a building, or observing if it will move parallel to a point taken a little to one side; should any deviation be manifested, loosen the cross-wire screws, and by the pressure of the hand on the head outside the tube, move the ring around until the error is corrected.

The wires being thus made respectively horizontal and vertical, fix their point of intersection on the object selected; clamp the instrument to the spindle, and having revolved the telescope, find or place some good object in the opposite direction, and at about the same distance from the instrument as the first object assumed.

Great care should always be taken in turning the telescope, that the position of the instrument upon the spindle is not in the slightest degree disturbed.

Now, having found or placed an object which the vertical wire bisects, unclamp the instrument, turn it half way around, and direct the telescope to the first object selected; having bisected this with the wires, again clamp the instrument, revolve the telescope, and note if the vertical wire bisects the second object observed.

Should this happen, it will indicate that the wires are in adjustment, and the points bisected are with the centre of the instrument, in the same straight line.

If not, however, the space which separates the wires from the second point observed, will be double the deviation of that point from a true straight line, which may be conceived as drawn through the first point and the centre of the instrument, since the error is the result of two observations, made with the wires when they are out of the optical axis of the telescope.

For as in the diagram, let A represent the centre of the instrument, and B C the imaginary straight line, upon the extremities of which the line of collimation is to be adjusted.

B represents the object first selected, and D the point which the wires bisected, when the telescope was made to revolve.

When the instrument is turned half around, and the telescope again directed to B, and once more revolved, the wires will bisect an object, E, situated as far to one side of the true line as the point D is on the other side.

The space, D E, is therefore the sum of two deviations of the wires from a true straight line, and the error is made very apparent.

In order to correct it, use the two capstan head screws on the sides of the telescope, these being the ones which affect the position of the vertical wire.

Having by means of these screws, moved back the vertical wire until, by estimation, one-quarter of the space D E, has been passed over, return the instrument to the point B, revolve the telescope, and if the correction has been carefully made, the wires will now bisect a point C, situated midway between D and E, and in the prolongation of the imaginary line, passing through the point B and the centre of the instrument.

To ascertain if such is the case, turn the instrument half around, fix the telescope upon B, clamp to the spindle and again revolve the telescope towards C. If the wires again bisect it, it will prove that they are in adjustment, and that the points, B, A, C, all lie in the same straight line. Should the vertical wire strike to one side of C, the error must be corrected precisely as above described, until it is entirely removed.

As the makers of the instruments always place the cross hairs at exactly right angles to each other, if the vertical hair is kept plumb, the other will be at right angles to it.

THE CHAIN OR STEEL TAPE AND PINS.

The chain should be made of annealed steel wire, each link exactly 1 ft. in length. The links should be so made as to reduce the liability to kink to a minimum. All joints should be brazed, and handles at each end of D shape, or modifications of D shape, should be provided. These handles should be attached to short links at each end, and the combined length of each of these short links and one handle, should be exactly 1 ft. The handles should be attached to the short link in such a manner that the chain may be slightly lengthened or shortened by screwing up a nut at the handle. It should be divided every 10 ft. with a brass tag, on which either the number of points represents the number of tens from the front end, or the number of tens may be designated by figures stamped on the tags.

When a chain is purchased, one that has been warranted as "Correct, U. S. Standard," should be selected, and before using it, it should be stretched on a level surface, care being taken that it is straight, and no kinks in it, and the extremities marked by some permanent mark. These marks can be used in the future to test the chain. It should be tested frequently, and the length kept to the standard as marked when it was new.

In chaining, the chainmen should always remember the axiom that "*A straight line is the shortest distance between two points.*" Ordinarily the chain should be held horizontally, and if either end is held above the ground a plumb bob and line should be used to mark the end of the chain on the ground. If used on a regular incline, the chain may be stretched along the incline, and by having the amount of declination the horizontal and vertical distances may either be calculated or found in the Traverse Table.

The steel tape is simply a ribbon of steel, on which are marked, by etching, or other means, the different graduations, which may be down to inches or tenths of a foot, or may be only every foot. It is wound on a reel, and may be any desired length up to 500 ft.

Chains are usually in 50 and 100 ft. lengths.

For accuracy steel tapes are now almost exclusively used by the leading mining engineers of the anthracite regions, on account of their greater accuracy as compared with chains.

When distances do not come at even feet the fractional part of the foot should always be noted in tenths. Thus fifty-three feet and six inches should always be noted as 53·5 ft.

Pins.—Pins should be from 15 to 18 ins. long, made of tempered steel wire, and should be pointed at one end, and turned with a ring for a handle. When using a 50 ft. chain, a set of pins should consist of eleven, one of which should be distinguished by some peculiar mark. This should be the last pin stuck by the front chainman. When all eleven pins have been stuck, the front chainman calls "*Out!*" and the back chainman comes forward and delivers him the ten pins that he has picked up, and he notes the "out." When giving the distance to the transitman he counts his "outs," each of which consists of 500 ft., and adds to their sum the number of fifties as denoted by the pins in his possession, and the odd number of feet and fractional parts of a foot from the last pin to the front end of the chain.

These directions regarding "outs," apply only to cases where sights of over 550 ft. length are taken. The accuracy and value of a survey depend as much on the careful work of the chainmen as on anything else, and no one should be allowed to either drag or read the chain who is not intelligent enough to appreciate the importance of extreme accuracy.

The clinometer or slope level.—The clinometer is a very valuable instrument and should be always carried by the surveyor. It consists of a level tube so arranged that one end swings loose around the quadrant of a circle which is graduated every quarter or half a degree from 0° to 90°. When placed on a level surface the bubble will be in the centre of the tube, when the marker on the end of the tube is at zero. When placed on any pitching surface, and the tube is moved so that the bubble is in the centre, the marker will show on the quadrant exactly at the number of degrees of inclination.

COMPASS SURVEYING.

As was noted before, the compass should not be depended on except in cases of emergency, or for short surveys of comparative unimportance. With it, horizontal angles only can be measured, and the notes are, for field work very simple. A survey made with a compass requires very simple notes. As models for the student we give the following examples:

FIELD NOTES FOR AN OUTSIDE SURVEY.

Called place of beginning Station 1.

Stations.	*Bearings.*	*Distances.*
1 to 2.	N. 35° E.	270·0.

At 1 + 37 ft. crossed small stream 3 ft. wide.
At 1 + 116 ft. = first side of road.
At 1 + 131 ft. = second side of road.
At 1 + 137 ft. = blazed and painted pine tree, 3 ft. left, marked for a "go by."

Station 2 is a stake at foot of white oak tree, blazed and painted on four sides for corner.

2–3.	N. 83½° E.	129·0.

Station 3 is stake and stones corner.

3–4.	S. 57° E.	222·0.

3 + 64 ft. = centre of small stream 2 feet wide.
3 + 196 ft. = white oak "go by," 2 ft. right.

Station 4 = cut stone corner.

4–5.	S. 34¼° W.	355·0.

4 + 174 ft. = ledge of sandstone 10 ft. thick, dipping 27° south.

5–1.	N. 56½° W.	323·0.

5 + 274 ft. = ledge of sandstone 10 ft. thick, dipping 25° south (evidently continuation of same ledge as at 4 + 174).

Station 1 = place of beginning.

NOTES FOR A MINE SURVEY.

Set at a point in East Main Gangway, opposite centre of third cross hole to Air Gangway. Called place of beginning Station 1.

At Station 1, ribs 4 ft. right and 8 ft. left.

1-2.	N. 67½° E.	97·6.

Station 2 is opposite cross hole to Air Gangway, pillar 10 ft. thick.

At 1 + 50 ribs, 2 ft. right, 10 ft. left.
At 2 ribs, 6 ft. right, 6 ft. left.
Vein 6·4 ft. thick. Dip of vein, 16° Sth.

2-3.	N. 77¼° E.	163·4.

2 + 10 = first side of opening on left.
2 + 23 = second side of opening on left.
2 + 50 = 6 ft. right, 6 ft. left.
$\left.\begin{matrix}2 + 53 \\ + 65\end{matrix}\right\}$ = opening left.
3 is Face of Gangway, 4 ft. right, 8 ft. left.
Vein 6.5 ft. thick, coal good. Dip, 12° South.

The notes of a survey should always be dated, and the names of the party recorded. The pages of the note book should be numbered, and when future surveys are started from old points, or sights are taken to old stations, reference should be made in the notes to the page on which such stations were previously noted.

The notes given as examples can be greatly abbreviated in practice, but care should be taken not to make them unintelligible by too much abbreviation.

VERNIER OR TRANSIT SURVEYING.

In treating of surveying of this kind it may be said in the start, that the operator who has been making surveys with the compass for some time, is much better able to begin with the vernier than one who has had no experience with the needle. To make a vernier survey a transit with sliding plate and vertical circle must be had. The sliding plate is arranged under and on the outside edge of the compass box, and is divided into degrees and halves from 0 to 360°, while a small plate, call the vernier, above the lower, records the minutes. On the transit the compass plate is generally divided the same as the vernier plate and not into quadrants. In starting the survey the instrument must first be placed by means of a plummet directly over the point of beginning and leveled. The sliding plate is then set so that it coincides with 0 of the vernier, and the plate is then clamped and turned so that the north end of the needle corresponds with 0 on the compass plate. The lower screw is then fastened and the vernier plate screw loosened when the first sight is taken, and the course recorded by noticing beyond what number of degrees on the lower plate the 0 of the vernier points and the number of minutes beyond this, by counting on the vernier from 0 to where a line on the vernier exactly corresponds with one on the lower plate. As a check the needle course is recorded, which should nearly correspond with that of the vernier, according to the quantity of magnetic attraction by which it may be influenced. The instrument is then moved and set exactly on the point where the sight had just been taken and again leveled, great care being taken to have the same reading on the plate as was recorded at the previous sight. While the plates remain clamped the lower screw is loosened and a sight is taken back upon the point just left. When this is done the order is reversed, the lower screw being fastened and the vernier plate allowed to move and another sight ahead is taken and the course read. At this point, by referring to the needle, which has been mentioned heretofore to be used as a check, the course will be found to differ from the reading on the vernier 180°, or as near thereto as the magnetic attraction will permit. The needle being established as the meridian at the beginning of the survey, it will be seen at once that the reading on the vernier is not correct, but is recording a course directly opposite to the one being run, and in order to overcome this difficulty the true course is recorded by adding or subtracting the difference 180° after taking into consideration the direction of the survey. The instrument is then moved to the next station and the same course pursued and so continued throughout the whole of the survey, great care being constantly taken by using the needle as a check to avoid noting courses in opposite directions to the correct ones, and to bear in mind to note the distance between all stations and intermediate points.

The vertical circle is divided from 0 to 90° to the right and left of the centre, and has a vernier attached in order that slopes may be minutely recorded. taken either up or down. In taking an angle the sight must be taken to the rod or light at the same distance from the ground as is the telescope of the instrument. The angle is then recorded from the circle in the same manner as one from the vernier plate, and is marked plus or minus, according as the sight is taken up or down.

The distance between the points having been ascertained, the vertical height may be found by means of the Traverse Table or Table of Sines and Tangents.

In making a transit survey, the surveyor cannot make his notes too full. In a surface survey, both horizontal and vertical angles should be taken at every sight. Every physical characteristic, and all surface improvements should be noted and located. Every ledge of rock should be noted, its character, dip and course of strike should be taken. The stations should be made as permanent as possible. A notch and nail in the root of a tree or stump is far preferable to a stake and nail. A small hole drilled in a solid immovable rock is better still. In mine surveys, the more complete the notes the better. A mine map may be accurate enough, and still not be complete. The mine map should be a complete history of the colliery, showing also, indirectly, what its future may reasonably be expected to be. The main idea should be to get as much information as possible on the map.

To make a complete map, the engineer should first make a survey around the tract to be worked, locating all the prominent physical features and improvements. If he can do so, he should make a topographical map of the tract at once; but, if time is limited, by running the vertical as well as the horizontal angle, he can carry the tidal elevation or the elevation above some assumed datum, to every station, and *mark it on the map at that point.* Then as he makes subsequent surveys, he can gradually get data enough to make a fairly complete topographical map in course of time. Every ledge of rock in place, should be located, and the amount and direction of its dip, as well as the character of the rock, should be marked neatly on the map. The streams of water on the tract should be regarded as of primary importance, and should be located with exactness.

After the surface survey has been made and plotted, a survey should be carefully carried into the workings and the same care taken in reading the vertical angles. *Mark the elevation carefully at every station. Take the dip of the vein at every station, and oftener if it changes between stations.* If the vein worked is a thick one, note how far the station is above the bottom slate, if above it at all. Note the thickness of the vein, and take frequent sections of it. Locate all faults and state the character of each fault. Locate the ribs of all pillars with accuracy. Don't attempt to make a pretty map by drawing the sides of openings parallel to each other; draw them as they are. Note all pillars that have been robbed out, and those that have been skipped. Designate such pillars by some standard mark to distinguish them from pillars that still remain intact. In running the survey through a tunnel, take a section of it, noting carefully the dips and character of each bench of rock. Do the same in shafts. Take advantage of every opportunity to "tie up" the survey by connecting with some other branch of it by running through cross cuts or any other openings. Take advantage of the second outlet to carry the survey to the surface by a route different from that by which the mine was entered, and tie up with the outside survey. "Don't shove," is a short and an appropriate expression.

If the surveys don't tie, don't shove them so that they apparently will; rerun them until you find the error that has thrown you out. If you have tied up at every opportunity, the chances are you will not have far to look for the error. Use what good sense you have been blessed with. This will direct you in regard to noting other features not already mentioned. Always bear in mind that your notes cannot be too complete. Don't be afraid of filling your note book. Note books are cheap, and they were made to be filled. Keep your notes as neatly and in as condensed a form as is consistent with clearness.

Base all your work on one meridian. If you have a number of collieries in the same neighborhood, don't have as many different meridians, or you will never know how they lie in their relation to each other, and the difference in meridians will be an endless source of annoyance.

Test your instruments frequently and see that they are in perfect adjustment. Don't trust the magnetic needle if you want to make an accurate survey and map. Test your chain or steel tape as frequently as you do your transit. An inaccurate chain and a poor chainman are as great sources of error as a transit that is out of adjustment and a careless transitman.

Let your mine map be the ventilating chart of the mine. Mark the upcast and downcast plainly on it, and show the course of the air currents by arrows.

With mine maps constructed on these lines, collieries can be worked more economically and with greater safety. More coal can be taken out at less expense, and advantage can be taken of innumerable natural and other features that, without such a map, would be lost sight of.

If a cross section is desired, on any line through the tract, the data to construct it can be taken directly from the map. If a change is desired in the method of ventilating it can readily be planned on the map. If mechanical haulage is desired the necessary data for the mechanics can be taken from the map. If it is desired to rob pillars in any portion of the colliery the superintendent can see at a glance whether it can be done with safety to the outside improvements and the inside workings or not. If there are any streams on the tract, they can be readily kept from finding their way to the inside workings, and thus the duty of the pumping engines can be kept down to a minimum.

PLOTTING.

Plotting consists of reproducing on paper the lines of a survey, on any scale that the surveyor thinks best. For mine maps, a scale of 100 ft. per inch will be found most convenient.

The necessary instruments are a draughting board or table, a T-square or a parallel ruler, a protractor and a scale.

If a T-square is used the edges of the draughting board or table must be planed very accurately, so that slight errors are not magnified on the long blade of the T-square. For extensive maps the T-square should not be used.

The T-square is generally made of hard wood, and is constructed in the shape of the letter T. The blade or stem may be either rigidly set at right angles to the head, or it may swing on a pivot, and be arranged with clamp screws that will permit of its being set at any angle. The head is placed against the edge of the table or board, and the blade is used as a ruler to mark or carry the meridian to any portion of the map.

The parallel ruler is simply a ruler set on rollers that are very accurately turned to exactly the same size and so constructed that parallel lines may be drawn by simply rolling it from place to place on the paper. Parallel rulers of a cheap form are made by joining two straight edges with two or more strips of metal of exactly the same length, fastened to the straight edges in such a manner that they are parallel to each other, and the ends revolve around a pivot. Then by setting one straight edge on any line, a parallel line may be drawn by moving the other straight edge to the desired place.

The protractor consists of a circle or a semi-circle graduated into degrees and fractional parts of degrees. The semi-circle is the most convenient. It is often supplied with a blade, to which is attached a vernier, and with it minutes as well as degrees or half and quarter degrees can be plotted. The semi-circular protractor with a blade and vernier reading to minutes is the most convenient style and is therefore preferred by most draughtsmen. The scale is simply a rule divided into inches and these are subdivided into different divisions, as required by the draughtsman. The most convenient scale is the triangular boxwood or steel scale which has six different graduations, as follows:

(1) The inches are divided into tenths; (2) inches divided into twentieths; (3) inches divided into thirtieths: (4) inches divided into fortieths; (5) inches divided into fiftieths; (6) inches divided into sixtieths.

In addition to the above named instruments, there are dozens of others of more or less value to the draughtsman. Principal of these are, wooden, rubber or metallic triangles, ruling pens, dividers, curve boards, bow pens, etc. The paper on which the map is to be drawn should be tacked down to the table or board, and should be covered with squares each exactly 10 ins. square. The sides of these squares should be the meridians, or North and South lines, and the tops and bottoms should run due East and West. Mark the first station on the paper, set your parallel ruler or T-square on the meridian nearest it and with the protractor produce the course to the next station. Measure the distance with a scale, and proceed in this manner to plot all the courses, using each time the meridian nearest the station the course is taken from. After all the stations have been plotted, fill in the side notes, marking everything on the map with great care and neatness. Always use the horizontal distances. All surveys should be traversed, and all plotting should be either checked by the traversing, or the principal stations should be plotted by use of the traverse.

To calculate the vertical distances.—When making the survey read the vertical angles to all stations. If the angle is one of depression note it with a

minus sign (—) preceding it. If it is an angle of elevation precede it with a plus sign (+). These will show whether the vertical distance is to be added to or subtracted from the height of the preceding station.

Having the horizontal distance and the vertical angle:

Distance × tangent of vertical angle=Departure or vertical distance.

Having the pitch distance and vertical angle:

Distance × sine of vertical angle=Departure, or vertical distance.

To calculate the horizontal distance or latitude.—Pitch distance × cosine of vertical angle=Horizontal distance or latitude.

Vertical height, or departure ÷ sine of vertical angle=Horizontal distance or latitude.

To calculate the pitch distance.—Horizontal distance or latitude ÷ cosine of bearing, or multiplied by secant of bearing=Pitch distance.

Vertical distance or departure ÷ sine of vertical angle, or multiplied by co-secant of bearing=Pitch distance.

To calculate the vertical angle.—The horizontal distance or latitude ÷ the pitch distance = Cosine of vertical angle.

Vertical distance or departure ÷ pitch distance = Sine of vertical angle.

Vertical distance, or departure ÷ horizontal distance or latitude = Tangent of vertical angle.

Note.—Whenever sines, cosines, tangents, etc., are here named, they mean the natural sines, etc., of an arc described with a radius equal to *one*. A table of natural sines is published in this volume. There is also a table of logarithmic sines, etc., and of logarithms of numbers, by the use of which the calculations may be shortened. (See tables of Logarithms of Numbers and Logarithmic Sines, Tangents, etc.)

To traverse a survey.—To traverse a survey, means to determ'ne by calculation how far North or South and East or West any station may be from another, the location of which is fixed. To do this, all distances must be either measured horizontally, or calculated to horizontal distances. The horizontal angles, or courses must be either read as quadrant courses or reduced from azimuth to quadrant courses. An azimuth course is one that is read on the transit which is graduated from 0° to 360°. A quadrant course is one read in the quadrant of the circle, as S. 67° W., N. 43° E., etc.

Latitude means distance north or south, and is determined by the first initial of the recorded course. Thus, if a course is S. 67° W., the latitute is south; if N. 43° E., the latitude is north.

Departure means distance east or west, and is determined by the last initial of the recorded course. Thus if a course is S. 67° W., the departure is west; if N. 43° E., the departure is east.

The latitude=Distance×cosine of bearing.

The departure=Distance×sine of bearing.

If the survey is a continuous one around a tract, and ending at the place of beginning, the sum of the Northings should equal the sum of the Southings; and the sum of the Eastings should equal the sum of the Westings. Or in other words the sum of all the latitudes north, should equal the sum of all the latitudes south; and the sum of all the departures east, should equal the sum of all the departures west. It is evident that by coming back to the place of beginning the surveyor has traveled the same distance north as he has south, and the same distance east as he has west.

The most accurate way to construct a map is to traverse the survey and place all stations on it by the traversed distances, or to at least put a number of the principal stations on the map by the traversed distances, and use the protractor only to plot the intermediate stations. If the map is constructed in this way, the convenience of the 10 inch squares mentioned before, will be at once seen by the draughtsman. They are also important in plotting with the protractor, because they reduce the chances of errors by the slipping of the parallel ruler, or inaccuracies of the edge of the table when the T-square is used, to a minimum. To illustrate plotting by use of the traversed distances, we will use the following example:

Stations.	Quadrant Courses.	Distances.	Latitudes.		Departures.	
			N.	S.	E.	W.
1 to 2	N. 35° E.	270·0	221·0		155·0	
2 to 3	N. 83° 30′ E.	129·0	15·0		128·0	
3 to 4	S. 57° E.	222·0		121·0	186·0	
4 to 5	S. 34° 15′ W.	355·0		293·0		200·0
			236·0	414·0	469·0	200·0

The foregoing table calculated according to formulæ for latitudes and departures, shows that Station 2 is 221·0 ft. North and 155·0 East of Station 1; and that Station 5 is 178·0 South and 269·0 ft. East of Station 1.

These stations, or stations 3 and 4, or all, may be placed on the map by simply making the two measurements for each station.

To find the area of a tract of land.—If a regular polygon, find the area by the rule given under the head of "Mensuration," for polygons of the same number of sides. If an irregular polygon, divide it into triangles and calculate the area of each triangle, the sum of these areas will be the area of the tract. If the tract is an irregular polygon in shape the map should be made on as large a scale as possible, and the distances should be measured with the greatest care, owing to liability to error through very slight inaccuracies of measurement.

To find the contents of a seam of coal under a tract.—If the seam lies flat, multiply the area of the tract in square feet, by the thickness of the seam in feet. The product will be the cubical contents of the seam in feet. If the seam is an inclined one, find its area by measuring the width of the tract on its line of pitch, and find the distance on the pitch of the seam by dividing the horizontal distance measured by the cosine of the angle of inclination. This will give you the pitch distance. Multiply the pitch distance by the length of the tract, and you will have the area of the seam. This multiplied by its thickness will give the contents.

To carry a survey down a shaft.—One of the most difficult things that the mine surveyor has to do, is to carry a meridian down a shaft. It is a task that requires great care and patience, and should never be done in a hurry. In addition to his other instruments, the surveyor should be provided with enough fine copper wire to make two plumb lines, each as long as the shaft is deep, and he should also have two weights or heavy plumb bobs, and two buckets of oil.

After he has brought his survey up to the shaft, he should set two points exactly in line, one on each side of the shaft, extending into the open area, far enough to keep the wire dropped from them from resting against the side of the shaft at any place along its whole length. Having set these points, he should drop a wire from each down the shaft, attach the weights or plummets, and let them swing in the buckets of oil. As soon as they have come to rest, he should set his instrument as nearly in line with them as possible, and move it gradually till he finds that the vertical cross hair in his telescope exactly strikes both plumb lines. Then, as his instrument has been set on the course of the marks at the head of the shaft, he has a meridian inside on which to base his survey. The location of the instrument is found by simply measuring from the plumb lines. Great care should be taken in this work, for a slight inaccuracy at the foot of the shaft will be greatly magnified at the face of the workings, if they are at all extensive.

LEVELING.

Instruments.—But two instruments are used—the level and a leveling rod. The level consists of a telescope to which is fitted on the under side a long level tube. The telescope rests in a Y at each end of a revolving bar, which is attached to a tripod head very similar to that used for a transit. The telescope is similar to the telescope of a transit. The leveling rod is merely a straight bar of wood, 6 ft. or more in length, divided into feet and tenths of a foot. A target divided into four equal parts by two lines, one parallel with the staff, and the other at right angles to it, and painted red and white so as to make it prominent at a distance, slides on the rod and is provided with a clamp screw. The centre of the target is cut out and a vernier, graduated decimally, is set in, which enables the rodman to read as close as $\frac{1}{1000}$ of a foot.

If a long rod is required, it is made of two sliding bars, which when closed are similar to a single rod as described above. When used at points where it is necessary to shove the target to a greater height than six or six and a half feet, the target is clamped at the highest graduation on the front of the rod, and the rod is extended by pushing up the back part, which carries the target with it. The readings in this case are made either from the vernier on a graduated side, or a vernier on the back. The rodman must always hold his rod perfectly plumb or perpendicular.

To adjust the level.—The proper care and adjustment of the level is of great importance. A very slight error in adjustment will completely destroy the utility of any work done.

To adjust the line of collimation, set the tripod firmly, remove the Y pins from the clips, so as to allow the telescope to turn freely, clamp the instrument to the tripod head, and, by the leveling and tangent screws, bring either of the wires upon a clearly marked edge of some object, distant from one to five hundred feet.

Then with the hand carefully turn the telescope half way around, so that the same wire is compared with the object assumed.

Should it be found above or below, bring it half way back by moving the capstan head screws at right angles to it, remembering always the inverting property of the eye piece; now bring the wire again upon the object, and repeat the first operation until it will reverse correctly.

Proceed in the same manner with the other wire until the adjustment is completed.

Should both wires be much out, it will be well to bring them nearly correct before either is entirely adjusted.

To adjust the level bubble.—Clamp the instrument over either pair of leveling screws, and bring the bubble into the centre of the tube.

. Now turn the telescope in the wyes, so as to bring the level tube on either side of the centre of the bar. Should the bubble run to the end it would show that the vertical plane, passing through the centre of the bubble, was not parallel to that drawn through the axis of the telescope rings.

To rectify the error, bring it by estimation half way back, with the capstan head screws, which are set in either side of the level holder, placed usually at the object end of the tube.

Again bring the level tube over the centre of the bar, and adjust the bubble in in the centre, turn the level to either side. and if necessary, repeat the correction until the bubble will keep its position, when the tube is turned half an inch or more, to either side of the centre of the bar.

The necessity for this operation arises from the fact, that when the telescope is reversed end for end in the wyes in the other and principal adjustment of the bubble, we are not certain of placing the level tube in the same vertical plane; and, therefore, it would be almost impossible to effect the adjustment without a lateral correction.

Having now, in great measure, removed the preparatory difficulties, we proceed to make the level tube parallel with the bearings of the Y rings.

To do this, bring the bubble into the centre with the leveling screws, and then, without jarring the instrument, take the telescope out of the wyes and reverse it end for end. Should the bubble run to either end, lower that end, or what is equivalent, raise the other by turning the small adjusting nuts, on one end of the level, until by estimation half the correction is made; again bring the bubble into the centre and repeat the whole operation, until the reversion can be made without causing any change in the bubble.

It would be well to test the lateral adjustment, and make such correction as may be necessary in that, before the horizontal adjustment is entirely completed.

To adjust the wyes.—Having effected the previous adjustments, it remains now to describe that of the wyes, or, more precisely, that which brings the level into a position at right angles to the vertical axis, so that the bubble will remain in the centre during an entire revolution of the instrument.

To do this, bring the level tube directly over the centre of the bar, and clamp the telescope firmly in the wyes, placing it as before, over two of the leveling screws, unclamp the socket, level the bubble, and turn the instrument half way around, so that the level bar may occupy the same position with respect to the leveling screws beneath.

Should the bubble run to either end, bring it half way back by the Y nuts on either end of the bar; now move the telescope over the other set of leveling screws, bring the bubble again into the centre, and proceed precisely as above described, changing to each pair of screws, successively, until the adjustment is very nearly perfected, when it may be completed over a single pair.

The object of this approximate adjustment, is to bring the upper parallel plate of the tripod head into a position as nearly horizontal as possible, in order that no essential error may arise, in case the level, when reversed, is not brought precisely to its former situation. When the level has been thus completely adjusted, if the instrument is properly made, and the sockets well fitted to each other and the tripod head, the bubble will reverse over each pair of screws in any position.

Should the engineer be unable to make it perform correctly, he should examine the outside socket carefully to see that it sets securely in the main socket and also notice that the clamp does not bear upon the ring which it encircles.

When these are correct, and the error is still manifested, it will probably be in the imperfection of the interior spindle.

After the adjustments, of the level have been effected, and the bubble remains in the centre in any position of the socket, the engineer should carefully turn the telescope in the wyes, and sighting upon the end of the level, which has the horizontal adjustments along each side of the wye, make the tube as nearly vertical as possible.

When this has been secured, he may observe, through the telescope, the vertical edge of a building, noticing if the vertical hair is parallel to it; if not, he should loosen two of the crosswire screws at right angles to each other and with the hand on these, turn the ring inside, until the hair is made vertical; the line of collimation must then be corrected again, and the adjustments of the level will be complete.

To use the level.—When using the instrument, the legs must be set firmly into the ground, and neither the hands nor person of the operator be allowed to touch them; the bubble should then be brought over each pair of leveling screws successively, and leveled in each position, any correction being made in the adjustments that may appear necessary.

Care should be taken to bring the wires precisely in focus, and the object distinctly in view, so that all errors of parallax may be avoided.

This error is seen when the eye of an observer is moved to either side of the centre of the eye-piece of a telescope, in which the foci of the object and eye-glasses are not brought precisely upon the crosswires and object; in such a case the wires will appear to move over the surface, and the observation will be liable to inaccuracy.

In all instances the wires and object should be brought into view so perfectly that the spider lines will appear to be fastened to the surface, and will remain in that position however the eye is moved.

If the socket of the instrument becomes so firmly set in the tripod head as to be difficult of removal in the ordinary way, the engineer should place the palm of his hand under the wye nuts at each end of the bar, and give a sudden upward shock to the bar, taking care also to hold his hands so as to grasp it the moment it is free.

The field work.—If the survey has been carefully made and vertical angles taken at every sight, leveling will be necessary only in cases where extreme accuracy in regard to vertical heights is necessary. In most cases of practical work at collieries, particularly in determining thickness of strata, general rise or fall of an inside road, etc., etc., the elevations calculated by the use of the vertical angle will be close enough, but there are frequently instances when leveling must be done to insure success in certain work. In this connection it is well to state that if the transit telescope is supplied with a long level tube, and it is as a whole in first class adjustment, levels can be successfully run with it, if the transitman uses due care. In running levels the note book should be ruled and the columns headed as follows:

Station.	Backsight	Foresight.	Height of Instrument.	Elevation.	Remarks.

Having his instrument in proper adjustment and his note book ruled the levelman is ready to proceed with the work.

The rodman holds the rod on the starting point, the elevation of which is either known or assumed. The levelman sets up his instrument somewhere in the direction in which he is going, but not necessarily, or usually in the precise line. He then sights to the rod and notes the reading as a backsight or + (plus) sight; entering it in the proper column of his note book, and adding it to the elevation of the starting point as the "height of instrument." The rodman then goes ahead about the same distance, sets his rod on some well defined and solid point, and the levelman sights again to the target, which the rodman moves up or down the rod till it is exactly bisected by the horizontal cross-hair in the telescope, as he did when giving the backsight. This reading is noted as a foresight or — (minus) sight. The foresight subtracted from the height of instrument gives the elevation of the second station. The rodman holds this latter point, and the levelman goes ahead any convenient distance, backsights to the rod, and proceeds as before. In this case we have assumed that levels are only being taken between regular stations or two extreme points.

If a number of points in close proximity to each other are to be taken, the rodman after giving the backsight holds his rod at each point desired. The readings of any number in convenient sighting distance are taken and recorded as foresights and any descriptive notes are made in the column of remarks. These are each subtracted from the height of instrument and the elevation

found is noted in column headed elevation. After all the intermediate points are taken the rodman goes ahead to some well defined point which is called a "turning point" (T. P.) in the notes. The elevation of this is found and recorded. The rodman remains at this point until the levelman goes ahead, sets up and takes a backsight. This backsight reading added to the elevation of the turning point gives a new height of instrument from which to subtract new foresights, and thus obtain the elevation of the next set of points sighted to.

When running levels over a long line the levelman should set frequent "Bench Marks." These are any permanent well defined marks that can be readily found and identified at any future time. By leveling to them he has secured the elevation of points from which to start any subsequent levels that may be necessary. A good bench mark can always be made on the side or root of a large tree or stump by chopping it away so as to leave a wedge shaped projection with the point up. Drive a nail in the highest point of this to mark where the rod was held, and blaze the tree or stump above the bench mark. In this blaze, either cut or paint the number of the bench mark, which should of course correspond with the number in the note book. In the mines, prominent frogs or castings in the main roads, if permanent, make good bench marks.

As an example of the correct way to keep the level notes, we append the following:

Station.	B. S.	F. S.	H. Inst.	Elev.	Remarks.
1				100·0	Assumed Elevation of Station 1.
	3·412		103·412		
2		4·082		99·330	Station 2 of Survey. See page ...., vol....
		6·791		96·621	Sight taken to ground at N. E. cor. Jno. Smith's house.
3 = T. P.		4·862		98·550	Station 3 of Survey noted above.
	11.698		110·248		
4		9·817		100·431	Station 4 of Survey noted above.
B. M. 1		6·311		103·937	B. M. 1 is on north side of large white oak.
5		6·427		103·821	Station 5 of Survey noted above.

PROOF OF CALCULATIONS.—The calculations are proven by adding together the Backsights and also the Foresights taken to turning points and last station. Their difference equals the difference of level between the starting point and last station. Thus:

Foresights.	Backsights.
4·862	3·412
6·427	11·698
11·289	15·110
	11·289
	3·821 = 103·821—100·0 or 3·821.

TO CONSTRUCT A CROSS-SECTION FROM A WELL MADE MINE MAP.

To successfully construct a cross-section, the draughtsman should have a good knowledge of the local geology. With this, a well constructed map, and the following general ideas he can easily construct a good section:

(1.) Draw a line across the map through the points determined on.

(2.) Lay a narrow strip of tracing cloth on this line, draw on it the line and carefully mark on it all points desired with their elevation above a common datum. Do this for inside workings as well as the surface. Mark on it all of the "dips" given on the map, on the line or in close proximity to it.

(3.) Draw a line on the paper you are going to use, and tack the strip of tracing cloth down so that the line on it covers the line on the paper underneath.

(4.) With a needle point, prick all points noted on the tracing cloth, through to the paper and erect perpendiculars from them.

(5.) Assume some elevation as that of the datum line, and measure the elevation of all points on the surface above it, and mark these points. Draw lines connecting these points, and you will have the profile of the surface.

(6.) In the same manner mark the elevation of the inside workings by erecting perpendiculars and measuring the distance they are above the assumed elevation of the datum line. With a protractor draw the pitch given, through

each point which should be so placed as to locate the bottom slate of the vein. Connect these pitches as nearly as you can by your knowledge of the features of the vein, and you will have the profile of the bottom slate. Put the top of the vein on by drawing a line parallel to the bottom, the correct distance from the bottom slate. From your map take measurements that will enable you to show what portions of the vein are taken out, and what still remain solid. Mark the assumed elevation on the datum line, and also designate its course.

By following the above directions and working in the details, which differ in every case, a good cross section can be made through any well mapped tract without going in the field for notes.

THE THEORY OF STADIA MEASUREMENTS,

ACCOMPANIED BY TABLES OF HORIZONTAL DISTANCES AND DIFFERENCES OF LEVEL FOR THE REDUCTION OF STADIA FIELD OBSERVATIONS.*

BY ARTHUR WINSLOW,

Late Asst. Geologist, Second Geolog. Survey of Penna., State Geologist of Missouri.

The fundamental principle upon which stadia measurements are based, is the geometrical one that the lengths of parallel lines subtending an angle are proportional to their distances from its apex. Thus if, in *Fig.* 1, a represents the length of a line subtending an angle at a distance d from its apex, and a' the length of a line, parallel to and twice the length of a, subtending the same angle at a distance d' from its apex, then will d' equal $2d$.

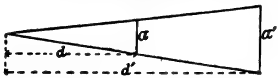


Fig. 1.

This is, in a general way, the underlying principle of stadia work; the nature of the instruments used, however, introduces several modifications, and these will be best understood by a consideration of the conditions under which such measurements are generally made.

There are placed, in the telescopes of most instruments, fitted for stadia work, either two horizontal wires (usually adjustable) or a glass with two etched horizontal lines at the position of the cross wires, and equidistant from the centre wire.

A self-reading stadia rod is further provided, graduated according to the units of mersurement used.

In a horizontal sight with such a telescope and rod, the position of the stadia wires are projected upon the rod and intercept a distance which in *Fig.* 2 is represented by a.

In point of fact there is formed, at the position of the stadia wires, a small conjugate image of the rod which the wires intersect at points b and c, which are respectively the foci of the points B and C on the rod. If, for simplicity sake, the object glass be considered a simple bi-convex lens, then, by a principle of optics, the rays from any point of an object converge to a focus at such a position that a straight line, called a secondary axis, connecting the point with its image, passes through the *centre* of the lens. This point of intersection of the secondary axes is called the optical centre. Hence, it follows that lines such as c C and b B, in *Fig.* 2, drawn from the stadia wires through the centre of the object glass, will intersect

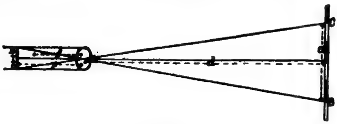


Fig. 2.

* Mr. Winslow's calculations and tables have been proven practically correct, by the several corps of the Second Geological Survey of Penna. The corps in the anthracite regions under directions of Mr. Frank A. Hill, Geologist in Charge, took over 30,000 stadia sights, and better results were obtained when tie surveys were made, than in previous work in which distances were chained.

the rod at points corresponding to those which the wires cut on the *image* of the rod. From this follows the proportion:

$$\frac{d}{p} = \frac{a}{I} \therefore d = \frac{p}{I} a \ldots\ldots (1)$$

Where: d = the distance of the rod from the centre of the objective;
p = the distance of the stadia wires from the centre of the objective;
a = the distance intercepted on the rod by the stadia wires;
I = the distance of the stadia wires apart.

If p remained the same for all lengths of sight, then $\frac{p}{I}$ could be made a desirable constant and d would be directly proportional to a. Unfortunately, however, for the simplicity of such measurements, p (the focal length) varies with the length of the sight, increasing as the distance diminishes and *vice versa*. Thus, the proportionality between d and a is variable.

The object, then, is to determine exactly what function a is of d and to express the relation in some convenient formula.

The general formula for bi-convex lenses is:

$$\frac{1}{p} + \frac{1}{p'} = \frac{1}{f} \ldots\ldots (2)$$

f is the *principal* focal length of the lens, and p and p' are the focal distances of image and object and are *approximately* the same as p and d, respectively, in equation (1):

$$\text{therefore, } \frac{1}{p} + \frac{1}{d} = \frac{1}{f}, \text{ approximately.}$$

$$\text{and } \frac{d}{p} = \frac{d}{f} - 1$$

$$\text{From (1), } \frac{d}{p} = \frac{a}{I}$$

$$\therefore \frac{a}{I} = \frac{d}{f} - 1$$

$$\text{whence, } d = \frac{f}{I} a + f \ldots\ldots (3)$$

In this formula, it will be noticed that, as f and I remain constant for sights of all lengths, the factor by which a is to be multiplied is a constant, and that d is thus equal to a constant times the length of a, plus f. This formula would seem, then, to express the relation desired, and it is generally considered as the fundamental one for stadia measurements. As above stated, however, the equation $\frac{1}{p} + \frac{1}{d} = \frac{1}{f}$ is only *approximately* true, and the conjunction of this formula with (2) being, therefore, not rigidly admissible, equation (3) does not express the exact relation.* The equation expressing the true relation, though differing from (3) in value, agrees with it in form, and also, in that the expression corresponding to $\frac{f}{I}$ is a constant, and that the amount to be added remains, practically, f. The constant corresponding to $\frac{f}{I}$ may be called k†, and thus the distance of the rod from the objective of the telescope is seen to be equal to a constant times the reading on the rod, plus the principal focal length of the objective. To obtain the exact distance to the *centre* of the

* This is demonstrated later on.

† k is dependent upon I and can, therefore, be made a convenient value in any instrument fitted with adjustable stadia wires. It is generally made equal to 100, so that a reading on the rod of 1′ corresponds to a distance of 100′ + f.

instrument, it is further necessary to add the distance of the objective from that centre, to f; which sum may be called c. The final expression for the distance, with a horizontal sight, is then

$$d = ka + c \quad \text{.....} (4)$$

The necessity of adding c is somewhat of an incumbrance. In the stadia work of the U. S. Government surveys an approximate method is adopted in which the total distance is read directly from the rod. For this method the rod is arbitrarily graduated, so that, at the distance of an average sight, the same number of units of the graduation are intercepted, between the stadia wires on the rod, as units of length are contained in the distance. For any other distance, however, this proportionality does not remain the same; for, according to the preceding demonstration, the reading on the rod is proportional to its distance, not from the centre of the instrument, but from a point at a distance "c" in front of that centre; so that, when the rod is moved from the position where the reading expresses the *exact* distance, to a point, say half that distance from the instrument centre, the reading expresses a distance *less* than half; and, at a point double that distance from the instrument centre, the distance expressed by the reading is *more* than twice the distance. The error for all distances less than the average being minus, and for greater distances plus. The method is, however, a close approximation, and excellent results are obtained by its use.

For stadia measurements with inclined sights there are two modes of procedure. One, is to hold the rod at right angles to the line of sight; the other, to hold it vertical. With the first method it will be seen, by reference to *Fig.* 3, that the distance read is not to the foot of the rod, E, but to a point f, vertically under the point F, cut by the centre wire. A correction has, therefore, to be made for this. An objection to this method is the difficulty of holding the rod at the same time in a vertical plane and inclined at a definite angle. Further, as the rod changes its inclination with each new position of the transit, the vertical angles of back and fore sight are not measured from the same point.

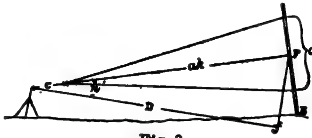


Fig. 3.

The method usually adopted is the second one where the rod is always held *vertical*. Here, owing to the oblique view of the rod, it is evident that the space intercepted by the wires on the rod varies, not only with the distance, but also with the angle of inclination of the sight. Hence, in order to obtain the true distance from station to station, and also its vertical and horizontal components, a correction must be made for this oblique view of the rod. In *Fig.* 4,

$AB = a =$ the reading on the rod;
$MF = d =$ the inclined distance $= c + GF = c + k.CD$;
$MP = D =$ the horizontal distance $= d \cos n$
$FP = Q =$ the vertical distance $= D \tan n$
$n =$ the vertical angle;
$AGB = 2m$

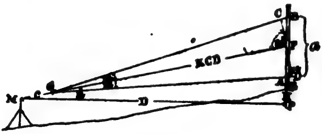


Fig. 4.

It is first required to express d in terms of a, n and m.

From the proportionality existing between the sides of a triangle and the sides of the opposite angles,

$$\frac{AF}{GF} = \frac{\sin m}{\sin [90° + (n-m)]}$$

$$\text{or, } AF = GF \sin m \frac{1}{\cos (n-m)};$$

$$\text{and } \frac{BF}{GF} = \frac{\sin m}{\sin [90° - (n+m)]}$$

$$\text{or, } BF = GF \sin m \frac{1}{\cos (n+m)};$$

$$\text{or } AF + BF = GF \sin m \left[\frac{1}{\cos(n-m)} + \frac{1}{\cos(n+m)} \right]$$

$$AF + BF = a, \text{ and } GF = \frac{CD}{2} \frac{1}{\tan m} = \frac{CD}{2} \frac{\cos m}{\sin m}$$

By substituting and reducing to a common denominator,

$$a = \frac{CD}{2} \frac{\cos m\,[\cos(n+m) + \cos(n-m)]}{\cos(n+m)\cos(n-m)}$$

Reducing this according to trigonometrical formulæ,

$$CD = a \frac{\cos^2 n \cos^2 m - \sin^2 n \sin^2 m}{\cos n \cos^2 m}$$

$$\text{as } d = MF = c + k.\ CD,$$

$$\therefore d = c + k\,a \frac{\cos^2 n \cos^2 m - \sin^2 n \sin^2 m}{\cos n \cos m^2}$$

The horizontal distance, $D = d \cos n$.

$$\therefore D = c \cos n + ka \cos^2 n - k\,a \sin^2 n \tan^2 m.$$

"The third member of this equation may safely be neglected, as it is very small even for long distances and large angles of elevation (for 1500′ $n = 45°$ and $k = 100$, it is but 0·07′). Therefore, the final formula for distances, with a stadia rod held vertically, and with wires equidistant from the centre wire, is the following:"

$$D = c \cos n + a\,k \cos^2 n \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

The vertical distance Q, is easily obtained from the relation : $Q = D \tan n$.

$$\therefore Q = c \sin n + a\,k \cos n \sin n$$

$$\text{or } Q = c \sin n + a\,k \frac{\sin 2n}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)^*$$

With the aid of formulæ (5) and (6), the horizontal and vertical distances can be immediately calculated when the reading from a *vertical* rod, and the angle of elevation, of any sight are given. I have calculated from these formulæ the stadia reduction tables following. The values of $a\,k \cos^2 n$ and $a\,k \frac{\sin 2n}{2}$ were separately calculated for each two minutes up to 30 degrees of elevation; but, as the value of $c \sin n$ and $c \cos n$ have quite an inappreciable variation for 1 degree, it was thought sufficient to determine these values only for each degree. As c varies with different instruments these last two expressions were calculated for three different values of c, thus furnishing a ratio from which values of $c \sin n$ and $c \cos n$ can be easily determined for an instrument having any constant (c).

The many advantages of stadia measurements in surveying need not be dwelt upon here, both because attention has been repeatedly called to them, and because they are self-evident to every engineer. Neither will it be within the compass of this article to describe the various forms of rods and instruments, or the conventionalities of stadia work.

A few precautions, necessary for accurate work, should, however, be emphasized. First, as regards the special adjustments: care should be taken that in setting the stadia wires† allowance be made for the instrument constant, and

---

* The above demonstration is substantially that given by Mr. George J. Specht, in an article on Topographical Surveying in Van Nostrand's Engineering Magazine for February, 1880, though enlarged and corrected.

† This applies to an instrument with movable stadia wires, and not one with etched lines on glass. In the latter case the graduation of the rod is the adjustable portion. It has been claimed as an advantage for etched lines on glass, that they are not affected by variations of temperature while the distance between stadia wires is. A series of tests which I made with one of Heller & Brightly's transits, to determine this point, showed no appreciable alteration in the space between the wires, as measured on a rod 500 feet distant, with a range of temperature between that produced in the instrument by the sun of a hot summer's day and that produced by enveloping the telescope in a bag of ice.

that the wires are so set that the reading, at any distance, is less than the true distance by the amount of this constant.*

For accurate stadia work it is better to take the reading for both distances and elevations only at alternate stations and then to take them from both back and fore sights, in such a manner that the vertical angle is always read from the same position on each rod, which should be the average height of the telescope at the different stations. If it be desired to have the absolute elevation of the ground under the instrument, the height of the telescope at each station will have to be measured by the rod, and the difference between this measurement and the average height used in sighting to the rod either added or substracted as the case may be. This difference will ordinarily be so small that in a great deal of stadia work no reduction will be necessary. In sighting to the rod for the angle of depression or elevation, the centre horizontal wire must always be used. By this means an exactly continuous line is measured. Cases will, of course, occur where this method will be impracticable, and then the mode of procedure must be left to the judgment of the surveyor.

For theoretical exactness it is necessary that the stadia wires should be equidistant from the centre horizontal wire, for, if this be not the ease, the distance read is for an angle of elevation differing from the true one by an amount proportional to the displacement of the wires.

With reasonable care a high degree of accuracy can be attained in stadia measurements. The common errors of stadia reading are unlike the common errors of chaining, the gross ones (such as making a difference of a whole hundred feet) being, in general, the only important ones, and these are readily checked by double readings. To facilitate the substraction of the reading of one cross hair from that of another, one should be put upon an even foot mark, and in the check reading the other one.

As stated in the preceding discussion, the generally accepted formula expressing the relation between the distance in a horizontal sight, the reading on the rod, the distance of the stadia wires apart, and the focal length of the objective is

$$d = \frac{f}{I}a + f \quad \ldots\ldots\ldots\ldots \quad (3)$$

where d, a, I and f represent these factors respectively.

This formula is derived from the conjunction of the two equations:

$$d = \frac{p}{I}a\,; \quad \ldots\ldots\ldots\ldots \quad (1)$$

$$\text{and } \frac{1}{p} + \frac{1}{p'} = \frac{1}{f}\,; \quad \ldots\ldots\ldots\ldots \quad (2)$$

p and p' in (2), being considered as equal to p and d in (1), which, it will be remembered, are the distances from the *centre* of the objective to the image and object respectively. But the general formula for lenses (2) is derived on the supposition that p and p' are measured from the *exterior faces* of the lens, and therefore p and d in (1) are each greater, by half the thickness of the lens, than p and p' in (2). Further, this formula is derived on the supposition that the object glass of the telescope is a simple, biconvex lens, whereas, in fact, it is a compound lens composed of a plano concave and a biconvex lens. Now, though these points may seem insignificant in themselves, they may influence the final result, as a difference of only 1 in the denominator of such a fraction as $\frac{1,000,000}{2}$ may alter the result by as much as 500,000. Considerable thought and time has, therefore, been given to the consideration of the effect of these corrections, and, as a result, it was found that the formula (3) does not express the true relation even within practical limits; and that if it were attempted to calculate the distance, d, by this formula, when the factors f, p and a were given, a result would be obtained which would differ considerably from the real distance. The inaccuracy lies in the expression $\frac{f}{I}$. The one to be substituted for it is, however, like it, a constant for each instrument; and, as we determine

* This is assuming the measurements to be made by the ordinary method, and not by the approximate one of the U. S. Engineers.

the value of this constant by actual trial and not from a knowledge of the values of f and I, the correction to be made will not affect the practice.

Considering first the case of a telescope with a simple, biconvex lens, the optical centre, being here, in the centre of the lens, d and p, in equation (1), as before stated, are measured from the centre of the lens, while, in equation (2), p and p' are measured from the exterior faces. If the thickness of the lens be taken as $2x$, then

p in equation (1) = p in equation (2), minus x; and
p' " " = d " " " x.

Therefore, while (1) remains $d = \frac{p}{I} a$, or $p = \frac{I}{a} d$ ....(1a),

by substitution (2), becomes, $\frac{1}{p - x} + \frac{1}{d - x} = \frac{1}{f}$ ....(2a).

Substituting $d \frac{I}{a}$ for p in (2a)

and reducing, we have

$$d = \frac{(I + a)\ (x + f)}{2\,I} + \sqrt{\frac{[(I + a)\ (x + f)]^2}{4\,I^2} - \frac{a}{I}(x^2 + 2\,x f)} \quad \text{.......(3a)}$$

This is the *exact* formula corresponding to (3), for biconvex lenses. This can, however, be considerably reduced without materially affecting its value. With a telescope of the dimensions of that of an ordinary engineer's transit, the term $\frac{a}{I}(x^2 + 2\,x f)$ diminishes the result by about ½ of an inch, and, therefore, may be neglected. Formula (3a) then becomes:

$$d = \frac{(I + a)\ (x + f)}{I}$$

$$= \frac{Ix + If + ax + af}{I}$$

$$= a\,\frac{x + f}{I} + f + x$$

The addition of x (half the thickness of the object glass) would be inappreciable in the length of any ordinary sight, and may be omitted. The final expression becomes, then:

$$d = \frac{x + f}{I}\,a + f \quad \text{..........(3b)}$$

This formula, it will be observed, differs from (3), in that the reading on the rod (a) is multiplied by $x + f$ instead of f. The numerical difference between the results is seen in the following examples:

Consider first the case with a one-foot reading on the rod, and let

$x = 18''$, $f = 9{\cdot}00''$, and $I = {\cdot}08''$.*

Formula (3) becomes, then:

$$d = \frac{9{\cdot}00''}{{\cdot}08''}\,12{\cdot}00 + 9{\cdot}00'' = 1359'' = 113{\cdot}25';$$

Formula (3b) becomes:

$$d = \frac{{\cdot}18'' + 9{\cdot}00''}{{\cdot}08''}\,12{\cdot}00'' + 9{\cdot}00'' = 1386 = 115{\cdot}50'$$

Difference = $2{\cdot}25'$

* These are very closely the dimensions in Heller & Brightly's large Surveyor's Transit 5-inch needle, as kindly furnished me by Mr. Heller. The magnifying power of the telescope was 28 diameters.

When the reading on the rod is 5 feet (or 60″), then (3) becomes:

$$d = \frac{9 \cdot 00''}{\cdot 08''} 60 \cdot 00'' + 9 \cdot 00'' = 563 \cdot 25';$$

and (3*b*) becomes:

$$d = \frac{\cdot 18'' + 9 \cdot 00''}{\cdot 08''} 60 \cdot 00'' + 9 \cdot 00'' = 574 \cdot 50'$$

$$\text{Difference} = \overline{11 \cdot 25'}\,*$$

The above demonstration shows, then, that, with a simple biconvex object glass, the usually accepted formula expressing the relation between the distance, the reading on the rod, the distance of the stadia wires apart, and the focal length of the objective, is not accurate even within the limits of accuracy of such measurements. With the usual combination of lenses in objectives this error would still remain. The derivation of a formula similar to (3*b*), for such lenses, would, however, be extremely difficult and would only hold for the special lens in question. For, with such a combination of lenses, the optical centre would no longer remain in the centre of the lens, but would vary its position according to the relative thicknesses of the two glasses, their radii of curvature and their indices of refraction; and, after its position had been determined by abstruse calculation and refined experiments, its distance from the two exterior faces of the compound lens would be expressed by *two different* values (x and x') instead of two equal values (x); and this would very much complicate further calculation.

It was seen that, in the newly deduced formula, for biconvex objectives, like that heretofore accepted, the factor by which the reading on the rod is multiplied, is a constant for each instrument, and that the practical method of adjusting the instrument remains the same. The question now arises, does this remain the case with a compound objective?

It view of the difficulty of demonstrating this mathematically, it was decided to make a practical test of this point with a carefully adjusted instrument. A distance of 500 feet was first measured off on a level stretch of ground, and each 50 foot point accurately located. From one end of this line three successive series of stadia readings† were then taken from the first 50 foot and each succeeding 100 foot mark. The following table contains the results:

Distances.	Spaces Intercepted on the Rod.			
	1st Series.	2d Series.	3d Series.	Mean.
Feet.	Feet.	Feet.	Feet.	Feet.
50·00	·4850	·4860	·4855	·4855
100·00	·9850	·9870	·9830	·9850
200·00	1·9850	1·9860	1·9840	1·9850
300·00	2·9890	2·9875	2·9870	2·9878
400·00	3·9830	3·9800	3·9890	3·9840
500·00	4·9850	4·9850	4·9900	4·9867

Multiplying the mean of these readings by 100 and subtracting the result from the corresponding distance, we obtain the following table:

Distances.	Mean of Stadia Readings times 100.	Differences.	Variations from Mean.
Feet.	Feet.	Feet.	Feet.
50·00	48·55	1·45	+ ·02
100·00	98·50	1·50	+ ·07
200·00	198·50	1·50	+ ·07
300·00	298·78	1·22	— ·21
400·00	398·40	1·60	+ ·17
500·00	498·67	1·33	— ·10

Sum of differences = 8·60;
Mean of difference = 1·43.

*As the difference is evidently proportional to the length of sight, with a 1000′ sight it would amount to 22.5′, etc.

† The readings were taken from two targets set so that the sight should be horizontal and thus also preventing any personal error or prejudice from affecting the reading.

The variations between the numbers of the column of differences are slight, the maximum from a mean value of 1·43 feet being only ·21 feet. A study of the tables will show that these variations have no apparent relation to the length of the sight, and as, in the maximum case, the variation corresponds to a reading on the rod of only ·0021 feet (an amount much within the limits of accuracy of any ordinary sight), we are perfectly justified in concluding that these variations are accidental, and that the "difference" is, for all practical purposes, a *constant* value.*

We thus see that with a telescope having a compound, plano-convex objective, whatever the formula may be, expressing the relation between d, f, x, etc., the horizontal distance is equal to a *constant* times the reading on the rod plus a *constant*, and may, as in the other cases, be expressed by the equation,

$$d = ak + c\dagger$$

The following tables, for the reduction of stadia field observations, have been computed from formulæ (5) and (6) respectively:

The vertical columns, in the tables, consist of two series of numbers for each degree, which series represent respectively the different values of $a\,k \cos^2 n$ and $ak\frac{\sin 2n}{2}$ for every two minutes, when $a\,k = 100$. To obtain the horizontal distance (D) or the difference of level (Q), in any case, the corresponding value of $c \cos n$ or $c \sin n$ must further be added, and the mean of each of these expressions for every degree is given under each column for three of the most common values of c.

EXAMPLE.—Let it be required to find the horizontal distance and the difference of level when:

$$n = +\,6°\ 18',$$
$$a\,k = 570, \text{ and}$$
$$c = ·75.$$

In the column headed 6°, opposite 18′, in the series for "Hor. Dist.," we find 98·80 as the expression for $a\,k \cos^2 n$, when $a\,k = 100$; therefore, when $a\,k = 570$;

$$a\,k \cos^2 n = 98·80 \times 5·70 = 563·16.$$

---

* Mr. Benjamin Smith Lyman has kindly furnished me with the following deductions from the above tables, as an indication of the exactness of stadia measurements:

Distances.	Variations from mean.	Error (or variation from mean) in parts of the distance measured.	Mean magnitude.
50 ft.	+·07 —·03 +·02	+·00133 —·00066 +·00033	·000777
100 "	+·07 —·13 +·27	+·00066 —·00133 +·00266	·001555
200 "	+·07 —·03 +·17	+·00033 —·00016 +·00083	·000444
300 "	—·33 —·18 —·13	—·00111 —·00061 —·00044	·000722
400 "	+·27 +·57 —·33	+·00066 +·00142 —·00083	·000972
500 "	+·07 +·07 —·43	+·00013 +·00013 —·00086	·000377
			6)·004841
			·000808

"We see then that the mean of the errors is ·000808 (or 1-1237), which, so far as the insufficient number of eighteen sights can show, would be the mean of the errors of an infinite number of trials, and would correspond to a probable error of ·000683, or 1-1464 for any one of the number of trials (that is, in general, for any trial) of the same kind. This is nearly two-thirds the exactness I claimed as possible for the stadia, with a telescope magnifying ten times linear, in my paper published in the Franklin Institute Journal (May and June, 1868). The difference may be due, perhaps, to some cause which I did not consider, such as a slight leaning of the rod forward or backward, inexactness in placing the face of the rod precisely at the station, imperfect graduation of the rod, imperfect cleanliness or transparency of the glasses or of the air, imperfection in the shape of the lenses or in their adjustments to one another, inferior lighting of the magnified image as compared with the unmagnified one, waviness from the varying refraction of the air, with the warm air rising from the sun-heated ground, inaccurate focusing, inexact placing of the centre hair upon the centre of the target, or graduation. This last difficulty might be avoided by taking one edge of the upper or lower cross hairs, and by special painting of the target for the centre hair. * * * But at any rate the superior exactness of stadia measurement over chaining is shown, so far as eighteen trials could do it."

† This may seem a statement of what was already a well known fact. But, heretofore, it has been assumed to be a direct deduction from optical principles, and as, according to the preceding article, this is not so clearly evident, it seemed necessary to redetermine the point.

To this must be added $c \cos n$, which, in this case, is found in the subjoined column to be ·75.

Therefore the required horizontal distance is

$$563{\cdot}16 + {\cdot}75 = 563{\cdot}91.$$

In a similar manner the required difference of level is

$$+\,10{\cdot}91 \times 5{\cdot}70 + {\cdot}08 = +\,62{\cdot}27.$$

One multiplication and one addition must be made in each case.

It is to be noticed, that, with the smaller angles, $\cos n$ in the expression $c \cos n$, and $c \sin n$ may be entirely neglected without appreciable error.

For values of c, which differ from those given, an approximate correction, proportional to the amount of difference may very easily be made in these two expressions.

M.	0°		1°		2°		3°		4°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0′, . .	100·00	·00	99·97	1·74	99·88	3·49	99·73	5·23	99·51	6·96
2, . .	"	·06	"	1·80	99·87	3·55	99·72	5·28	"	7·02
4, . .	"	·12	"	1·86	"	3·60	99·71	5·34	99·50	7.07
6, . .	"	·17	99·96	1·92	"	3·66	"	5·40	99·49	7·13
8, . .	"	·23	"	1·98	99·86	3·72	99·70	5·46	99·48	7·19
10, . .	"	·29	"	2·04	"	3·78	99·69	5·52	99·47	7·25
12, . .	"	·35	"	2·09	99·85	3·84	"	5·57	99·46	7·30
14, . .	"	·41	99·95	2·15	"	3·90	99·68	5·63	"	7·36
16, . .	"	·47	"	2·21	99·84	3·95	"	5·69	99·45	7·42
18, . .	"	·52	"	2·27	"	4·01	99·67	5·75	99·44	7·48
20, . .	"	·58	"	2·33	99·83	4·07	99·66	5·80	99·43	7·53
22, . .	"	·64	99·94	2·38	"	4·13	"	5·86	99·42	7·59
24, . .	"	·70	"	2·44	99·82	4·18	99·65	5·92	99·41	7·65
26, . .	99·99	·76	"	2·50	"	4·24	99·64	5·98	99·40	7·71
28, . .	"	·81	99·93	2·56	99·81	4·30	99·63	6·04	99·39	7·76
30, . .	"	·87	"	2·62	"	4·36	"	6·09	99 38	7·82
32, . .	"	·93	"	2·67	99·80	4·42	99·62	6·15	99·38	7·88
34, . .	"	·99	"	2·73	"	4·48	"	6·21	99·37	7·94
36, . .	"	1·05	99·92	2·79	99·79	4·53	99·61	6·27	99·36	7·99
38, . .	"	1·11	"	2·85	"	4·59	99·60	6·33	99 35	8·05
40, . .	"	1·16	"	2·91	99·78	4·65	99·59	6·38	99·34	8·11
42, . .	"	1·22	99·91	2·97	"	4·71	"	6·44	99.33	8·17
44, . .	99·98	1·28	"	3·02	99·77	4·76	99·58	6·50	99·32	8·22
46, . .	"	1·34	99·90	3·08	"	4·82	99·57	6·56	99·31	8·28
48, . .	"	1·40	"	3·14	99·76	4·88	99·56	6·61	99·30	8·34
50, . .	"	1·45	"	3·20	"	4·94	"	6·67	99·29	8·40
52, . .	"	1·51	99·89	3·26	99·75	4·99	99·55	6·73	99·28	8·45
54, . .	"	1·57	"	3·31	99·74	5·05	99·54	6·78	99·27	8·51
56, . .	99·97	1·63	"	3·37	"	5·11	99·53	6·84	99·26	8·57
58, . .	"	1·69	99·88	3·43	99.73	5·17	99·52	6·90	99·25	8·63
60, . .	"	1·74	"	3·49	"	5·23	99·51	6·96	99·24	8·68
c= ·75,	·75	·01	·75	.02	·75	·03	·75	·05	·75	·06
c=1·00,	1·00	·01	1·00	.03	1·00	·04	1·00	·06	1·00	·08
c=1·25,	1·25	·02	1·25	.03	1·25	·05	1·25	·08	1·25	·10

M.	5°		6°		7°		8°		9°		10°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0′, . .	99·24	8·68	98·91	10·40	98·51	12·10	98·06	13·78	97·55	15·45	96·98	17·10
2, . .	99·23	8·74	98·90	10·45	98·50	12·15	98·05	13·84	97·53	15·51	96 96	17·16
4, . .	99·22	8·80	98·88	10·51	98·48	12·21	98·03	13·89	97·52	15·56	96·94	17·21
6, . .	99·21	8·85	98·87	10·57	98·47	12·26	98·01	13·95	97·50	15·62	96·92	17·26
8, . .	99·20	8·91	98·86	10·62	98·46	12·32	98·00	14·01	97·48	15·67	96·90	17·32
10, . .	99·19	8·97	98·85	10·68	98·44	12·38	97·98	14·06	97·46	15·73	96·88	17·37
12, . .	99·18	9·03	98·83	10·74	98·43	12·43	97·97	14·12	97·44	15·78	96·86	17·43
14, . .	99·17	9·08	98·82	10·79	98·41	12·49	97·95	14·17	97·43	15·84	96·84	17·48
16, . .	99·16	9·14	98·81	10·85	98·40	12·55	97·93	14·23	97·41	15·89	96·82	17·54
18, . .	99·15	9·20	98·80	10·91	98·39	12·60	97·92	14·28	97·39	15·95	96·80	17·59
20, . .	99·14	9·25	98·78	10·96	98 37	12·66	97·90	14·34	97·37	16·00	96·78	17·65
22, . .	99·13	9·31	98·77	11·02	98·36	12·72	97·88	14·40	97·35	16·06	96·76	17·70
24, . .	99·11	9·37	98·76	11·08	98·34	12·77	97·87	14·45	97·33	16·11	96·74	17·76
26, . .	99·10	9·43	98·74	11·13	98·33	12·83	97·85	14·51	97·31	16·17	96·72	17·81
28, . .	99·09	9·48	98·73	11·19	98·31	12·88	97·83	14·56	97·29	16·22	96·70	17·86
30, . .	99·08	9·54	98·72	11.25	98·29	12·94	97·82	14·62	97·28	16·28	96·68	17·92
32, . .	99·07	9·60	98·71	11·30	98·28	13·00	97·80	14·67	97·26	16·33	96·66	17·97
34, . .	99·06	9·65	98·69	11·36	98·27	13·05	97·78	14·73	97·24	16·39	96·64	18·03
36, . .	99·05	9·71	98·68	11·42	98·25	13·11	97·76	14·79	97·22	16·44	96·62	18·08
38, . .	99·04	9·77	98·67	11·47	98·24	13·17	97·75	14·84	97·20	16·50	96·60	18·14
40, . .	99·03	9·83	98·65	11·53	98·22	13·22	97·73	14·90	97·18	16·55	96·57	18·19
42, . .	99·01	9·88	98·64	11·59	98·20	13·28	97·71	14·95	97·16	16·61	96·55	18·24
44, . .	99·00	9·94	98·63	11·64	98·19	13·33	97·69	15·01	97·14	16·66	96·53	18·30
46, . .	98·99	10·00	98·61	11·70	98·17	13·39	97·68	15·06	97·12	16·72	96·51	18·35
48, . .	98·98	10·05	98·60	11·76	98 16	13·45	97·66	15·12	97·10	16·77	96·49	18·41
50, . .	98·97	10·11	98·58	11·81	98·14	13·50	97·64	15·17	97·08	16·83	96·47	18·46
52, . .	98·96	10·17	98 57	11·87	98·13	13·56	97·62	15·23	97·06	16·88	96·45	18·51
54, . .	98·94	10·22	98·56	11·93	98·11	13·61	97·61	15·28	97·04	16·94	96·42	18·57
56, . .	98·93	10·28	98·54	11·98	98·10	13·67	97·59	15·34	97·02	16·99	96·40	18·62
58, . .	98·92	10·34	98·53	12·04	98·08	13·73	97·57	15·40	97·00	17·05	96·38	18·68
60, . .	98·91	10·40	98·51	12·10	98·06	13·78	97·55	15·45	96·98	17·10	96·36	18·73
c= ·75,	·75	·07	·75	·08	·74	·10	·74	·11	·74	·12	·74	·14
c=1·00,	·99	·09	·99	·11	·99	·13	·99	·15	·99	·16	·98	·18
c=1·25,	1·24	·11	1·24	·14	1·24	·16	1·23	·18	1·23	·21	1·23	·23

M.	11°		12°		13°		14°		15°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0′, . .	96·36	18·73	95·68	20·34	94·94	21·92	94·15	23·47	93·30	25·00
2, . .	96·34	18·78	95·65	20·39	94·91	21 97	94·12	23·52	93·27	25·05
4, . .	96·32	18·84	95·63	20·44	94·89	22·02	94·09	23·58	93·24	25·10
6, . .	96·29	18·89	95·61	20·50	94·86	22·08	94·07	23·63	93·21	25·15
8, . .	96·27	18·95	95·58	20·55	94·84	22·13	94·04	23·68	93·18	25·20
10, . .	96·25	19·00	95·56	20·60	94·81	22·18	94·01	23·73	93·16	25·25
12, . .	96·23	19·05	95·53	20·66	94·79	22·23	93·98	23·78	93·13	25·30
14, . .	96·21	19·11	95·51	20·71	94·76	22·28	93·95	23·83	93·10	25·35
16, . .	96·18	19·16	95·49	20·76	94·73	22·34	93·93	23·88	93·07	25·40
18, . .	96·16	19·21	95·46	20·81	94·71	22·39	93·90	23·93	93·04	25·45
20, . .	96·14	19·27	95·44	20·87	94·68	22·44	93·87	23·99	93·01	25·50
22, . .	96·12	19·32	95·41	20·92	94·66	22·49	93·84	24·04	92·98	25·55
24, . .	96·09	19·38	95·39	20·97	94·63	22·54	93·81	24·09	92·95	25·60
26, . .	96·07	19·43	95·36	21·03	94·60	22·60	93·79	24·14	92·92	25·65
28, . .	96·05	19·48	95·34	21·08	94·58	22·65	93·76	24·19	92·89	25·70
30, . .	96·03	19·54	95·32	21·13	94·55	22·70	93·73	24·24	92·86	25·75
32, . .	96·00	19·59	95·29	21·18	94·52	22·75	93·70	24·29	92·83	25·80
34, . .	95·98	19·64	95·27	21·24	94·50	22·80	93·67	24·34	92·80	25·85
36, . .	95·96	19·70	95·24	21·29	94·47	22·85	93·65	24·39	92·77	25·90
38, . .	95·93	19·75	95·22	21·34	94·44	22·91	93·62	24·44	92·74	25·95
40, . .	95·91	19·80	95·19	21·39	94·42	22·96	93·59	24·49	92·71	26·00
42, . .	95·89	19·86	95·17	21·45	94·39	23·01	93·56	24·55	92·68	26·05
44, . .	95·86	19·91	95·14	21·50	94·36	23·06	93·53	24·60	92·65	26·10
46, . .	95·84	19·96	95·12	21·55	94·34	23·11	93·50	24·65	92·62	26·15
48, . .	95·82	20·02	95·09	21·60	94·31	23·16	93·47	24·70	92·59	26·20
50, . .	95·79	20·07	95·07	21·66	94·28	23·22	93·45	24·75	92·56	26·25
52, . .	95·77	20·12	95·04	21·71	94·26	23·27	93·42	24·80	92·53	26·30
54, . .	95·75	20·18	95·02	21·76	94·23	23·32	93·39	24·85	92·49	26·35
56, . .	95·72	20·23	94·99	21·81	94·20	23·37	93·36	24·90	92·46	26·40
58, . .	95·70	20·28	94·97	21·87	94·17	23·42	93·33	24·95	92·43	26·45
60, . .	95·68	20·34	94·94	21·92	94·15	23·47	93·30	25·00	92·40	26·50
c= ·75,	·73	·15	·73	·16	·73	·17	·73	·19	·72	·20
c=1·00,	·98	·20	·98	·22	·97	·23	·97	·25	·96	·27
c=1·25,	1·22	·25	1·22	·27	1·21	·29	1·21	·31	1·20	·34

M.	16°		17°		18°		19°		20°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0′, . .	92·40	26·50	91·45	27·96	90·45	29·39	89·40	30·78	88·30	32·14
2, . .	92·37	26·55	91·42	28·01	90·42	29·44	89·36	30·83	88·26	32·18
4, . .	92·34	26·59	91·39	28·06	90·38	29·48	89·33	30·87	88·23	32·23
6, . .	92·31	26·64	91·35	28·10	90·35	29·53	89·29	30·92	88·19	32·27
8, . .	92·28	26·69	91·32	28·15	90·31	29·58	89·26	30·97	88·15	32·32
10, . .	92·25	26·74	91·29	28·20	90·28	29·62	89·22	31·01	88·11	32·36
12, . .	92·22	26·79	91·26	28·25	90·24	29·67	89·18	31·06	88·08	32·41
14, . .	92·19	26·84	91·22	28·30	90·21	29·72	89·15	31·10	88·04	32·45
16, . .	92·15	26·89	91·19	28·34	90·18	29·76	89·11	31·15	88·00	32·49
18, . .	92·12	26·94	91·16	28·39	90·14	29·81	89·08	31·19	87·96	32·54
20, . .	92·09	26·99	91·12	28·44	90·11	29·86	89·04	31·24	87·93	32·58
22, . .	92·06	27·04	91·09	28·49	90·07	29·90	89·00	31·28	87·89	32·63
24, . .	92·03	27·09	91·06	28·54	90·04	29·95	88·96	31·33	87·85	32·67
26, . .	92·00	27·13	91·02	28·58	90·00	30·00	88·93	31·38	87·81	32·72
28, . .	91·97	27·18	90·99	28·63	89·97	30·04	88·89	31·42	87·77	32·76
30, . .	91·93	27·23	90·96	28·68	89·93	30·09	88·86	31·47	87·74	32·80
32, . .	91·90	27·28	90·92	28·73	89·90	30·14	88·82	31·51	87·70	32·85
34, . .	91·87	27·33	90·89	28·77	89·86	30·19	88·78	31·56	87·66	32·89
36, . .	91·84	27·38	90·86	28·82	89·83	30·23	88·75	31·60	87·62	32·93
38, . .	91·81	27·43	90·82	28·87	89·79	30·28	88·71	31·65	87·58	32·98
40, . .	91·77	27·48	90·79	28·92	89·76	30·32	88·67	31·69	87·54	33·02
42, . .	91·74	27·52	90·76	28·96	89·72	30·37	88·64	31·74	87·51	33·07
44, . .	91·71	27·57	90·72	29·01	89·69	30·41	88·60	31·78	87·47	33·11
46, . .	91·68	27·62	90·69	29·06	89·65	30·46	88·56	31·83	87·43	33·15
48, . .	91·65	27·67	90·66	29·11	89·61	30·51	88·53	31·87	87·39	33·20
50, . .	91·61	27·72	90·62	29·15	89·58	30·55	88·49	31·92	87·35	33·24
52, . .	91·58	27·77	90·59	29·20	89·54	30·60	88·45	31·96	87·31	33·28
54, . .	91·55	27·81	90·55	29·25	89·51	30·65	88·41	32·01	87·27	33·33
56, . .	91·52	27·86	90·52	29·30	89·47	30·69	88·38	32·05	87·24	33·37
58, . .	91·48	27·91	90·48	29·34	89·44	30·74	88·34	32·09	87·20	33·41
60, . .	91·45	27·96	90·45	29·39	89·40	30·78	88·30	32·14	87·16	33·46
c= ·75,	·72	·21	·72	·23	·71	·24	·71	·25	·70	·26
c=1·00,	·96	·28	·95	·30	·95	·32	·94	·33	·94	·35
c=1·25,	1·20	·35	1·19	·38	1·19	·40	1·18	·42	1·17	·44

M.	21°		22°		23°		24°		25°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0′, . .	87·16	33·46	85·97	34·73	84·73	35·97	83·46	37·16	82·14	38·30
2, . .	87·12	33·50	85·93	34·77	84·69	36·01	83·41	37·20	82·09	38·34
4, . .	87·08	33·54	85·89	34·82	84·65	36·05	83·37	37·23	82·05	38·38
6, . .	87·04	33·59	85·85	34·86	84·61	36·09	83·33	37·27	82·01	38·41
8, . .	87·00	33·63	85·80	34·90	84·57	36·13	83·28	37·31	81·96	38·45
10, . .	86·96	33·67	85·76	34·94	84·52	36·17	83·24	37·35	81·92	38·49
12, . .	86·92	33·72	85·72	34·98	84·48	36·21	83·20	37·39	81·87	38·53
14, . .	86·88	33·76	85·68	35·02	84·44	36·25	83·15	37·43	81·83	38·56
16, . .	86·84	33·80	85·64	35·07	84·40	36·29	83·11	37·47	81·78	38·60
18, . .	86·80	33·84	85·60	35·11	84·35	36·33	83·07	37·51	81·74	38·64
20, . .	86·77	33·89	85·56	35·15	84·31	36·37	83·02	37·54	81·69	38·67
22, . .	86·73	33·93	85·52	35·19	84·27	36·41	82·98	37·58	81·65	38·71
24, . .	86·69	33·97	85·48	35·23	84·23	36·45	82·93	37·62	81·60	38·75
26, . .	86·65	34·01	85·44	35·27	84·18	36·49	82·89	37·66	81·56	38·78
28, . .	86·61	34·06	85·40	35·31	84·14	36·53	82·85	37·70	81·51	38·82
30, . .	86·57	34·10	85·36	35·36	84·10	36·57	82·80	37·74	81·47	38·86
32, . .	86·53	34·14	85·31	35·40	84·06	36·61	82·76	37·77	81·42	38·89
34, . .	86·49	34·18	85·27	35·44	84·01	36·65	82·72	37·81	81·38	38·93
36, . .	86·45	34·23	85·23	35·48	83·97	36·69	82·67	37·85	81·33	38·97
38, . .	86·41	34·27	85·19	35·52	83·93	36·73	82·63	37·89	81·28	39·00
40, . .	86·37	34·31	85·15	35·56	83·89	36·77	82·58	37·93	81·24	39·04
42, . .	86·33	34·35	85·11	35·60	83·84	36·80	82·54	37·96	81·19	39·08
44, . .	86·29	34·40	85·07	35·64	83·80	36·84	82·49	38·00	81·15	39·11
46, . .	86·25	34·44	85·02	35·68	83·76	36·88	82·45	38·04	81·10	39·15
48, . .	86·21	34·48	84·98	35·72	83·72	36·92	82·41	38·08	81·06	39·18
50, . .	86·17	34·52	84·94	35·76	83·67	36·96	82·36	38·11	81·01	39·22
52, . .	86·13	34·57	84·90	35·80	83·63	37·00	82·32	38·15	80·97	39·26
54, . .	86·09	34·61	84·86	35·85	83·59	37·04	82·27	38·19	80·92	39·29
56, . .	86·05	34·65	84·82	35·89	83·54	37·08	82·23	38·23	80·87	39·33
58, . .	86·01	34·69	84·77	35·93	83·50	37·12	82·18	38·26	80·83	39·36
60, . .	85·97	34·73	84·73	35·97	83·46	37·16	82·14	38·30	80·78	39·40
c= ·75,	·70	·27	·69	·29	·69	·30	·68	·31	·68	·32
c=1·00,	·93	·37	·92	·38	·92	·40	·91	·41	·90	·43
c=1·25,	1·16	·46	1·15	·48	1·15	·50	1·14	·52	1·13	·54

M.	26°		27°		28°		29°		30°	
	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0′, . .	80·78	39·40	79·39	40·45	77·96	41·45	76·50	42·40	75·00	43·30
2, . .	80·74	39·44	79·34	40·49	77·91	41·48	76·45	42·43	74·95	43·33
4, . .	80·69	39·47	79·30	40·52	77·86	41·52	76·40	42·46	74·90	43·36
6, . .	80·65	39·51	79·25	40·55	77·81	41·55	76·35	42·49	74·85	43·39
8, . .	80·60	39·54	79·20	40·59	77·77	41·58	76·30	42·53	74·80	43·42
10, . .	80·55	39·58	79·15	40·62	77·72	41·61	76·25	42·56	74·75	43·45
12, . .	80·51	39·61	79·11	40·66	77·67	41·65	76·20	42·59	74·70	43·47
14, . .	80·46	39·65	79·06	40·69	77·62	41·68	76·15	42·62	74·65	43·50
16, . .	80·41	39·69	79·01	40·72	77·57	41·71	76·10	42·65	74·60	43·53
18, . .	80·37	39·72	78·96	40·76	77·52	41·74	76·05	42·68	74·55	43·56
20, . .	80·32	39·76	78·92	40·79	77·48	41·77	76·00	42·71	74·49	43·59
22, . .	80·28	39·79	78·87	40·82	77·42	41·81	75·95	42·74	74·44	43·62
24, . .	80·23	39·83	78·82	40·86	77·38	41·84	75·90	42·77	74·39	43·65
26, . .	80·18	39·86	78·77	40·89	77·33	41·87	75·85	42·80	74·34	43·67
28, .	80·14	39·90	78·73	40·92	77·28	41·90	75·80	42·83	74·29	43·70
30, . .	80·09	39·93	78·68	40·96	77·23	41·93	75·75	42·86	74·24	43·73
32, . .	80·04	39·97	78·63	40·99	77·18	41·97	75·70	42·89	74·19	43·76
34, . .	80·00	40·00	78·58	41·02	77·13	42·00	75·65	42·92	74·14	43·79
36, . .	79·95	40·04	78·54	41·06	77·09	42·03	75·60	42·95	74·09	43·82
38, . .	79·90	40·07	78·49	41·09	77·04	42·06	75·55	42·98	74·04	43·84
40, . .	79·86	40·11	78·44	41·12	76·99	42·09	75·50	43·01	73·99	43·87
42, . .	79·81	40·14	78·39	41·16	76·94	42·12	75·45	43·04	73·93	43·90
44, . .	79·76	40·18	78·34	41·19	76·89	42·15	75·40	43·07	73·88	43·93
46, . .	79·72	40·21	78·30	41·22	76·84	42·19	75·35	43·10	73·83	43·95
48, . .	79·67	40·24	78·25	41·26	76·79	42·22	75·30	43·13	73·78	43·98
50, . .	79·62	40·28	78·20	41·29	76·74	42·25	75·25	43·16	73·73	44·01
52, . .	79·58	40·31	78·15	41·32	76·69	42·28	75·20	43·18	73·68	44·04
54, . .	79·53	40·35	78·10	41·35	76·64	42·31	75·15	43·21	73·63	44·07
56, . .	79·48	40·38	78·06	41·39	76·59	42·34	75·10	43·24	73·58	44·09
58, . .	79·44	40·42	78·01	41·42	76·55	42·37	75·05	43·27	73·52	44·12
60, . .	79·39	40·45	77·96	41·45	76·50	42·40	75·00	43·30	73·47	44·15
c= ·75,	·67	·33	·66	·35	·66	·36	·65	·37	·65	·38
c=1·00,	·89	·45	·89	·46	·88	·48	·87	·49	·86	·51
c=1·25,	1·12	·56	1·11	·58	1·10	·60	1·09	·62	1·08	·64

UNDERGROUND RAILWAYS.

Underground or mine car tracks should be solidly laid on good sills resting on the solid floor of the mine. They should be well ballasted, and should have good clean gutters on the lower side of the entry so that the rails may be protected as much as possible from the action of the mine water. The grades depend entirely on circumstances, but when possible the grade should be in favor of the load, and should be at least 5 inches in 100 ft. to ensure flow in the gutters alongside the track. The gauge of the track should not be less than 30 inches or more than 48 inches. A mean between these two, or a gauge of from 38 to 42 inches is desirable because it combines, to a certain extent, the advantages claimed for the extremes.

The advocates of broad gauges believe that the greater stability of the track and the consequent reduction in haulage expenses, the increased capacity of the broad gauge mine cars; the reduction in the outlay for rolling stock, and for repairs to the same, more than equal the disadvantages of broad as compared to the narrow gauges.

Advocates of the narrow gauges think that the ease of hauling around sharp curves, the reduction in cost of construction, and the use of mine cars with inside wheels, are advantages greater than those advanced by the advocates of the broad gauges.

The rails should be T-rail of regular section, varying in weight per yard from 18 lbs. to 50 lbs., according to service, and in some cases they are used as heavy as 70 lbs. per yard. Steel rails in the end are cheaper than iron rails.

Curves should be of as large radii as possible, and never of less radius than 25 ft.

The resistance of curves is very considerable. The less the radius of the curve, and the greater the length of the curved track occupied by the trip, or train, the greater the resistance. The length of wheel bases of the cars, the condition of rolling stock and of the track, and the rate of speed, all influence the resistance and there is no formula that will apply to all cases. In practice on surface railroads engineers compensate for curves on grades at the rate of 2/100 of a foot in each hundred feet for each degree of curvature, the grade being stated in feet per hundred. In mine work this compensation is not made, as the gain will not pay for the labor that must necessarily be employed to do work in a thoroughly scientific manner.

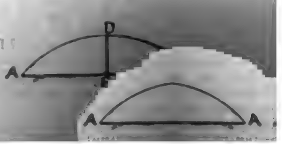
Sharper curves can be used on narrow gauge roads than on broad gauge roads, because the difference in length of the inner and outer rails on curves on the same degree is not quite so great, and also because the wheel bases of cars are less. The track should be spread about ¼ of an inch on easy curves, and on very short curves about an inch, or as much as the tread of the wheels will permit.

A good rule is to widen the track $\frac{1}{16}$ of an inch for each 2½ degrees of curvature.

Short and irregular curves are to be avoided whenever possible, as they increase the load and are destructive to rails and rolling stock. When a sharp curve is necessary the rail should be bent to the right curvature by a portable rail bender, or by a jack and clamps.

The outer rail of a curve should be slightly higher than the inner rail, but no set rule can be given, for the amount of elevation depends entirely on the gauge of track, design of cars and rate of speed.

Rules for measuring the radius of a curve.—Stretch a string, say 20 feet long, or longer if the curve is not a sharp one, across the curve corresponding to the line from A to C in the diagram. Then measure from B the centre of the line A-C, and at right angles with it, to the rail at D.



Multiply the distance A to B, or one-half the length of the string, in inches by itself; measure the distance D to B in inches, and multiply it by itself. Add these two products and divide the sum by twice the distance from B to D, measured exactly in inches and fractional parts of inches. This will give the radius of the curve in inches.

It may be more convenient to use a straight edge instead of a string. Care must be taken to have the ends of the string or straight edge touch the same part of the rail as is taken in measuring the distance from the centre. If the string touches the bottom of the rail flange at each end, and the centre measurement is made to the rail head, the result will not be correct.

In practice it will be found best to make trials on different parts of the curve to allow for irregularities.

EXAMPLE.—Let A-C be a 20 feet string; half the distance, or A-B, is then ten feet, or 120 inches. Suppose B-D is found on measurement to be 3 inches. Then 120 multiplied by 120 is 14,400, and 3 multiplied by 3 is 9; 14,400 added to 9 is 14,409, which, divided by twice 3, or 6, equals 2,401½ inches, or 200 feet 1½ inches, which is the radius of the curve.

The formula is thus stated, $\dfrac{AB^2 + BD^2}{2\,BD} = R$

Or applied to the above example, $\dfrac{120^2 + 9}{2 \times 3} = 2{,}401\tfrac{1}{2}$ in. $= 200$ ft. $1\tfrac{1}{2}$ in.

To find the radius of a circular railroad curve, the straight portions of a road being given.—If Q I and P D are the straight portions that are to be connected, the radius of the curve I D may be found as follows:

Produce Q I and P D until they meet and form the angle T. Bisect the angle Q T P by the line T E. From the point on either line from which the curve is to begin, in this instance making the point I the point of curve, erect the line I C perpendicular to Q T and the point where this joins the line T E, or C, is the centre of the curve, and the line I C is the radius. To find the end of the curve, or point of tangent, as D, draw a line from C, perpendicular to T P. The line C D will also be a radius of the circle of which I D is the arc and the point D will be the point of tanget.

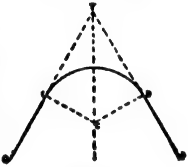


Fig. 1.

To find the radii of compound curves to join two straight portions of road.—This kind of curve is adopted where the railroad is required to pass through given points as C, D, E, F, or to avoid obstructions.

Compound railroad curves are composed of straight lines and circular arcs, and have common normals, O H, O P, P I, Q J, K R, and therefore common tangents where the arcs are joined. The normals are perpendicular to the straight portions of the road also; O H is perpendicular to A B, E F is perpendicular to Q J, and K R.

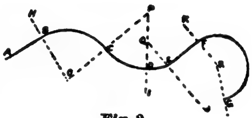


Fig. 2.

To find the radii O B, C Q, to connect two straight lines of railroad, A B, D E, the road has to pass from the point B, through the point C, and to touch the straight road E F at any point D.

Join B and C, make the angle B C O=O B C, which is supposed to be given, equal 90°—T B C. Draw B O perpendicular to A B, then O B=C O, and is the radius of the arc B C.

With O B as radius describe the arc B C; draw C F perpendicular to C Q, and produce D E to meet it in F, make D F=C F, and draw D Q perpendicular to E F, to meet C Q in Q. Then C Q=Q D, and the radii O B and Q D are determined.

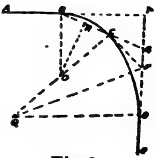


Fig. 3.

To bend rails to proper arc for any radius.—Rails are usually 30 ft. long, and the most convenient chord to use in bending mine rails is 10 ft.

Then having the radius and chord we find the rise of middle ordinate by squaring the radius, and from it take ¼ the square of the chord. Extract the square root of the remainder and subtract it from the radius; the result will be the rise or the middle ordinate. Thus having a radius of 30 ft. and a chord of 10 ft., the middle ordinate will be

$$30 - \sqrt{30^2 - 5^2} \text{ or } 0{\cdot}42 \text{ ft.}$$

SWITCHES.

The switch, or "latch" most commonly used in mines is shown in *Fig.* 4. When the branch or siding is in constant use an ordinary railway frog is substituted for the bar "*b*." The latches *a*, *a*, are wedge-shaped bars of iron (made as high as the rail) with an eye in the thick end. They are sometimes connected together by a rod attached to a lever so that they may both be moved at once from the side of the track, or by a person situated at some distance. This switch is made self-closing or automatic whenever it is necessary to run all the cars off at the branch (the switch then being used only to admit cars to the main track) by attaching the latches through a bar or lever to a metallic spring, a stick of some elastic wood, or a counter weight, to pull them back into a certain position whenever they have been pushed to one side or the other by the passage of a car on the main track.

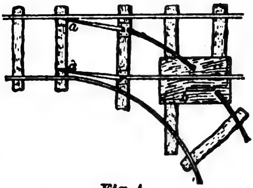


Fig. 4.

Figs. 7, 8, 10 and 11 show some of the applications of these spring latches or automatic switches. By a similar arrangement, in which *two* counterpoise weights are used, the car may be made to set the latches, and sometimes the car is depended upon to effect this without the assistance of counterweights. (See *Figs.* 10 and 11.)

The counterweights used for this purpose are usually set on a rocking arm or lever oscillating a short distance beyond the vertical on one side, and through a greater arc on the opposite side of the centre. The car opens the switch a certain distance moving the weight over the centre; the weight then falls, carrying the switch over, and setting the latch firmly against the rail.

A m dification of this switch is shown in *Fig.* 5, which represents a form of double switch. These latches are set by the drivers who kick them over and drop a small square of plate iron between them to hold them in place. This switch costs more than the other style and is better adapted to outside roads than to inside roads. The ordinary movable rail switch in common use on all surface railways is sometimes used in mine roads. It is commonly used in slopes arranged as shown by *Fig.* 9, to replace latches set by the car, and is also largely used in outside roads.

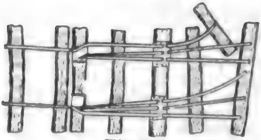


Fig. 5.

For crossings, ordinary railway frogs and grade crossings are sometimes used, as is also a small turntable, which then answers two purposes. More frequently the plan shown in *Fig.* 6, in which four movable bars are thrown across the main track whenever the other road is to be used, is adopted.

The subordinate road is built from 1⅛ to 2 in. higher than the main road to allow the bars to clear the main track rails.

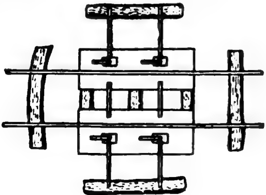


Fig. 6.

TURNOUTS.

On gangways or headings used as main haulage roads turnouts should be constructed at convenient intervals to allow the loaded and empty trips to pass. These turnouts should be long enough to accommodate from five or six up to fifteen or twenty cars. The switches at each end may be made self-acting so that the empty trip, coming in, is thrown on the turnout, and in running out on the main track at the other end the loaded cars open the switch which immediately closes.

As there is constant trouble with self-setting switches, either from small fragments of coal or slate clogging them up, or from insufficient power of the spring to move them, they are viewed with disfavor by many colliery managers who do not care to use them under any conditions.

SLOPE BOTTOMS.

At the foot of a slope, or at the landing on any lift, the gangway is widened out to accommodate at least two tracks—one for the empty and one for the loaded cars.

The empty track should be on the upper side of the gangway, or that side nearest the floor of the seam, and the loaded track on that side of the gangway nearest the roof of the seam.

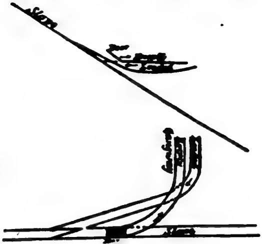


Fig. 7.

An arrangement of tracks often used is shown in *Fig.* 7. At a distance of 40 or 50 feet above the gangway the slope is widened out to accommodate the branch leading into the gangway loaded track. This branch descends with a gradually lessening inclination until nearly at the level of the gangway it turns into the main loaded track. A short distance above the gangway a bridge or door is placed, which, when closed, forms a latch by which the empty cars are taken off the slope. The empty track is about 6 ft. higher than the loaded track, and is carried over it on a trestle. The illustration in *Fig.* 7 shows the plan as arranged for a single slope, or one side only of a slope taking the coal from both directions. When coal is being raised from this lift the bridge is closed; the empty car comes down and is run off over the bridge; the car is unhooked from the rope, and the chain and hook, attached to the rope, are thrown down to the branch below on which a loaded car is standing; the loaded car is attached, the signal given, the car ascends to the main track on the slope, opening the switch—or the switch may be set each time by the bottom-men by means of a lever at the bottom of the branch.

This plan can only be economically applied in thick seams, as the height necessary to allow one track to cross the other on a trestle cannot be obtained in seams of moderate thickness without taking down a large amount of top.

A more simple plan, which dispenses with the bridge, is often used. The branch is laid off, as shown by *Fig.* 7, but near the point where it enters the gangway a switch, opening into the empty (a loaded) track, is placed.

By this arrangement the tracks cannot be as well arranged for handling, the cars by gravity as in the former plan, in which the empty cars when detached from the rope, run by gravity into the empty siding, and the loaded cars descend by gravity around the curve to the foot of the branch, where they lie ready to be attached to the rope. When the pitch of the slope is so steep that the coal falls out of the cars, the coal is raised in a gunboat or the cars are raised on a slope carriage—in either case the arrangement of the tracks at lift landings is entirely different. With either a gunboat or a slope carriage the arrangement of tracks on the slope is the same; but, in the former case, a connection between the slope and gangway tracks is often advisable.

When a gunboat is used the gangway tracks run direct to the slope, and a tipple, or dump, is placed on each side to dump the mine cars over the gunboat; but when the cars are raised on a slope carriage, the gangway tracks run direct (at right angles) to the slope to carry the car to the cage or carriage. The floor of the cage is horizontal, and has a track on it which fits on the end of the gangway track when the carriage is at the bottom, and this track is arranged with stops similar to those on cages used in shafts.

Another common arrangement of tracks at the bottom of a slope is shown by *Fig.* 8.

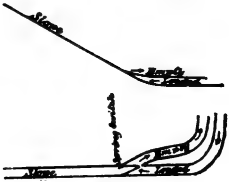


Fig. 8.

A branch is made by widening the slope out near the bottom, and this, being a few feet higher than the main track, is used to run off the empties by gravity. The loaded cars run in by gravity around the curve to the foot of the slope in position to be attached to the rope.

In ascending, the loaded car forces its way through the switch, or the switch may be set by a lever located at the foot of the slope. When the empty car descends it runs in on the branch, where the chain is unhooked and thrown over in front of the loaded car, and runs around the curve into the gangway by gravity.

It will be observed that in this plan the loaded car (and consequently the bottom-men) stands on the track in line with the slope, and in danger from any objects falling down the slope, or from the breakage of the rope or couplings; but this can be obviated by making the bottom on the curve. The illustration in *Fig.* 8 shows only one-half the slope; the other half is, of course, similar.

All of these plans necessitate the location of that part of the gangway near the slope, in the upper benches of the coal or near the top rock—the gangway is then curved gently around toward the floor, so that, when it has been driven far enough to leave a sufficiently thick pillar, the bottom bench is reached and the gangway is then driven along the bottom rock.

A very different bottom arrangement is shown by *Fig.* 9, which also represents a plan frequently adopted on surface planes.

The two slope tracks are merged into one a short distance from the bottom of the slope, and on the opposite side of the bottom two tracks curve around into the gangway on opposite sides of the slope. As these branches curve into the main gangway tracks, a switch sends off a side track for the empty cars.

The switch on the slope is either set by the car—and this can be done because the next loaded goes up on the same side on which the last empty descended—or by a lever located at the bottom.

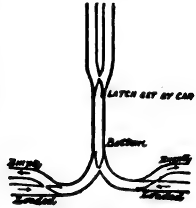


Fig. 9.

It will at once be seen that in this plan no opportunity is afforded of handling the cars by gravity. The curved branches are made nearly level, and the momentum of the descending car, if quickly detached, is often sufficient to carry it partly or wholly around the curve, even against a slight adverse grade. The disadvantage above noted of having the bottom in direct line with the slope (where there is danger from breakage and falling coal) also obtains in this plan.

In the plan shown by *Fig.* 10, the grades may be so arranged that the cars can be entirely handled by gravity.

The latches on the main slope track may be closed automatically by a spring or weight, the loaded car running through them in its ascent on the slope, or both sets may be operated by a single lever at the bottom. The switch at the upper end of the central track (loaded) is set by a hand lever. All three sets may be linked together, so that they can all be properly set by a single lever.

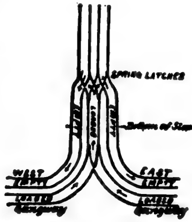


Fig. 10.

Reference to *Fig.* 8 will show that this is only a modification of that method. It requires space at the bottom for only three tracks, while the former requires width to accommodate four tracks, but is objectionable because it is more complicated. The extra set of latches at the top of the central track, and the curvature of both main tracks into this central one, must inevitably cause much trouble and delay from cars jumping the track at this point.

The plan shown in *Fig.* 11 is open to many of the objections pertaining to some of those already described, and which need not be reiterated here. It can only be employed in thick seams, or in seams of moderate thickness lying at a slight angle or dip.

In planning the arrangement of tracks on a slope, it is advisable to place as few switches as possible on the slope itself; to keep the main track unbroken; to make the tracks as straight as possible; to have nothing standing at the bottom in direct line with the slope tracks; and to arrange the tracks so that cars are handled by gravity.

The arrangement of tracks near the top of the slope, and on the surface, is often very similar to the bottom arrangements, as already described; but as all loaded cars (except rock and slate cars, which are run off on a separate switch) are to be sent off on one track, and all the empties come in on the same track to the head of the slope, and as there is usually abundance of room for tracks and sidings, these top ar-

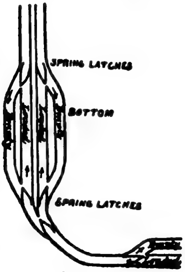


Fig. 11

rangements are in a measure much more easily designed. In some instances the two main slope tracks run into a single track near the head of the slope—a plan somewhat similar to the bottom arrangement shown by *Fig.* 9—and the cars are then brought to the surface on one track, which, after passing the knuckle, bifurcates into a loaded and empty track. A similar arrangement is frequently adopted at slopes on which a carriage or gunboat is used. When the two main slope tracks are continued up over the knuckle to the surface—the most common and best plan—the arrangement of tracks and switches may be planned entirely with a view to the quickest and most economical method of handling the cars.

VERTICAL CURVES AT TOPS AND BOTTOMS OF SLOPES AND PLANES.

The vertical curves at the knuckle and bottom of a slope or plane should have a sufficiently large radius, that when passing over them, the car will rest on the rail with both front and back wheels. The wheel base of the car must be considered in adopting the radius for these curves, for if the curve is of too short a radius, there is danger of the car jumping the track every time it passes over the curve. *Fig.* 12 shows, in an exaggerated degree, the car passing over curves that are of too small a radius. The defects and remedy are both apparent at a glance.

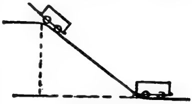


Fig. 12.

PLAN OF TRACKS FOR BOTTOM OF SHAFT.

Fig. 13 shows the arrangement of tracks at the foot of a shaft, with one of the cages at surface. The grades should be so arranged that from the inside latches of the crossings, the empty track should have a slight down grade from the shaft, and the loaded track a slight down grade toward the shaft. The crossings and the short straight piece of road close to the shaft should be level.

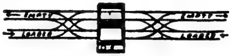


Fig. 13.

As it is often desired to move empty cars from one side of the shaft to the other, without stopping the hoisting, a narrow branch road should be cut through she shaft pillar, and used for this purpose. Where the pitch of the seam prevents this, a road should be laid alongside the shaft, room to accommodate it being cut out of the rock, on the side most desirable.

ARRANGEMENT OF TRACKS, ETC., AT HEADS OF SLOPES AND SHAFTS.

The arrangement of the tracks on the surface naturally differs at every colliery, owing to the different existing conditions. All surface roads should be so arranged that the loaded cars can be moved with the least possible power, always looking out for the return of the empties, with as little expenditure of power as possible. To secure the running of the loaded cars from the mouth of the shaft or slope by gravity, a slight grade is necessary, the amount of which depends on the friction of the cars, which varies greatly. Care should be taken that an excessive grade is not constructed, or there will be trouble in returning the empties from the dump to the head of the shaft or slope.

Where the conditions are such that the loaded cars can be run by gravity to the dump, a good plan is to have a short incline equipped with an endless chain, in the empty track. The empty cars can be run to the foot of this, hoisted by machinery to the top, and thus gain height enough to run them back to the shaft, or slope, by gravity.

At the Philadelphia & Reading Coal and Iron Co.'s Ellangowan Colliery, where the tipple at the head of the breaker is above the level of the head of the shaft, the following plan is used:

The loaded cars are taken off the east side of the cages, and run by gravity to the foot of an incline, where they are grasped by hooks on an endless chain and pulled up to the tipple. These hooks grasp one of the axles of the mine car. After being dumped, the car is run back from the tipple to the head of the incline, and is carried to the foot of the empty track of the incline by endless chain. This foot of the empty track is several feet higher than that of the loaded track, and the cars are run by gravity around to the west side of the cages, and are put on from that side. The empty cars, as they run on the cage, have momentum enough to start the loaded car off the cage and on toward the

foot of the incline. There are a number of hooks attached to both the empty and loaded chain on the incline, and there are often several loaded and several empty cars on different parts of the plane at once. This arrangement permits of the hoisting of from 700 to 800 cars per day out of a shaft 110 yards deep, with single deck cages.

Another excellent arrangement for the handling of coal on the surface is the invention of Mr. Robert Ramsey, and has been adopted by the H. C. Frick Coke Co., and a number of other prominent operators. A description of this arrangement, as applied at the H. C. Frick Coke Co.'s Standard Shaft, is as follows:

The landing of the shaft is made slightly higher than the level of the tipple, which is north of the shaft. South of the shaft is located a double steam ram, one ram being directly in line with the track on each cage. Directly in front of the rams is a transfer truck, worked east and west by wire rope. The loaded car on the cage is run by gravity to the tipple, where it is dumped by means of a nicely balanced dumping arrangement. As soon as it is empty it rights itself, and runs by gravity alongside of the shaft to the transfer truck, which carries it up a grade to a point directly in line with the cage that is at the landing, and one of the steam rams pushes it on the cage, and at the same time starts the loaded car off toward the tipple. This second loaded car is then returned by the same means to the opposite cage. The whole mechanism is operated by one man, by means of conveniently arranged levers, each of which is automatically locked, except when the proper time to use it arrives. It is, therefore, impossible for the topman to work the wrong lever, and put an empty car into the wrong compartment of the shaft. Besides the one man at the levers, there is but one other man employed at the tipple, and his work is solely to look after the cars when dumping. All switches are worked automatically, and the average hoisting at this shaft is at the rate of three wagons per minute. The shaft is about 250 ft. deep, and single deck cages are used.

The Lehigh & Wilkes-Barre Coal Co. has a system in use at a number of collieries that has also proven very effective. In this system the loaded cars are run by gravity from the cage to the dump, and the empties are hauled from the dump back to a transfer truck, by a system of endless rope haulage. The transfer truck carries it to a point opposite the back of the cage. The empty car runs by gravity to the cage, and its momentum starts the loaded car, on the cage, on its way to the dump. This system necessitates the employment of more topmen, but is a very good one. At the Nottingham shaft, which is 470 ft. from landing to landing, from 140 to 150 cars per hour are hoisted on single deck cages.

LIGHT.

Velocity of light, 192,000 miles per second, nearly.

SOUND.

Velocity in	Feet per second.	Velocity in	Feet per second.
Air	1,142	Copper	10,378
Water	4,900	Wood	12,000 to 16,000
Iron	17,500		

Distant sounds may be heard on a still day:

	Yards.		Yards.
Human voice	150	Military band	5,200
Rifle	5,300	Cannon	35,000

TO MEASURE DISTANCES BY SOUND.

RULE.—Multiply the time the sound takes in seconds by 1,142; the product will be the distance in feet.

NOTE.—Sound in common air moves uniformly at the rate of about 1,142 ft. in a second. Cold and uneven surfaces retard its motion a little, and heat accelerates it in a small degree.

EXAMPLE 1.—I observed the flash of a gun 30 seconds before I heard the report. How far was it from me?

Answer.—$30 \times 1.142 = 34,260$ ft.

EXAMPLE 2.—I observed a flash of lightning, and after six strokes of my pulse I heard the thunder, and my pulse makes 66 strokes in a minute. How far was the thunder distant from me.

Answer.—1 mile 255·3 yards.

THE FRICTION OF MINE CARS.

The friction of mine cars varies so much that it is impossible to give a formula for calculating it in every case. No two mine cars will show the same frictional resistance, when tested with a dynamometer, and therefore nothing but an average friction can be dealt with. The construction of the car, the condition of the track and the lubrication are important factors in determining the amount of friction.

In this connection we may, however, state some of the requisites of good oil box and journal bearings. Tightness is a prerequisite, and in dry mines where the dust is very penetrating, this is especially important; the bearings should be sufficiently broad; the oil box large enough to hold sufficient oil to run a month without renewal, and so constructed that, while it may be quickly and easily opened, it will not open by jarring, or by being accidently struck by a sprag or lump of coal.

There are a number of patented self-oiling wheels that are improvements on the old style plain wheels, and each of these have undoubtedly some point of superiority over the old style.

Among the most extensively used of these patent wheels are those with annular oil chambers and those with patent bushings. Their superiority consists in the fact that, if properly attended to, a well lubricated bearing is secured with greater regularity and less work than when the old style wheel was used.

With a view of adopting a standard wheel, the Susquehanna Coal Co. experimented for a number of years with different styles of self-lubricating wheels, and has recently adopted one of the following description: The outer end of the hub is closed, and the wheel is fastened to the axle by a spring cotter-pin, passed through one of two plugged holes which are opposite each other. Dirt is prevented from entering the open end by a cap with faced end and packing-ring, fitting over the end of the hub. The lubricant is introduced into the oil chamber through one of the plugged holes in the hub. When the wheel is in motion the lubricant is thrown, by centrifugal force, away from the axle, enters two ports, and is carried, by spiral channels, again into contact with the axle; the surplus oil being again carried back to the oil chamber. The lubrication is effected by oil adhering to and being swept back and forth along the axle in an open zigzag slit, when passing through the ends of the oil channels away from the oil chamber, where the section and height of the channels are smallest, the back of the oil channel being conical, with the largest end out, and the radial height of the channel from the axle decreasing as it recedes from the oil chamber. This style of wheel was the outcome of months of experiments, and has been patented by Mr. J. H. Bowden, the inventor, who is chief engineer of the company.

Mr. R. Van A. Norris, E.M., Assistant Engineer, made a series of 989 tests with old style wheels, some of which had patent removable bushings, and others annular oil chambers, and the Bowden wheel. The old wheels were found to be practically alike in regard to friction. All of the wheels were of the loose outside type, 16 ins. in diameter, mounted on 2⅛ in. steel axles, with journals 5¼ in. long. The axles passed loosely through solid cast boxes, bolted to the bottom sills of the cars, and were not expected to revolve.

The table of friction tests shows the results obtained with both old and new style wheels, and is of interest to all colliery managers, inasmuch as the figures given for the old style wheels alone, are the most complete in existence, and as stated before they are good averages.

Tests were made on the starting and running friction of each style of wheel, under the conditions of empty and loaded cars, level and grade track, curves and tangents. The instruments used were a Pennsylvania Railroad spring dynamometer, graduated to 3,000 lbs. with a sliding recorder, a hydraulic gauge (not recording) reading to 10,000 lbs., graduated to 25 lbs. and a spring balance, capacity 300 lbs., graduated to 3 lbs. All these were tested and found correct previous to the experiments.

Most of the observations on single cars were made with the 300 lb. balance. The two types of "old style" wheels have been classed together in the table. Each car was carefully oiled before testing, and several of each type were used, the results being averages from the number of trials shown in the table.

SUMMARY OF FRICTION-TESTS ON SUSQUEHANNA COAL CO.'S MINE-CARS, APRIL, 1889.

DIMENSIONS OF WHEELS.
16 inches, diameter of tread.
$2\frac{1}{8}$ inches, diameter of axle.
$5\frac{1}{4}$ inches, length of journal.

	Old Style Wheels. Empty. Weight of car.	Empty. Tractive force per car.	Empty. Tractive force due to gravity.	Empty. Tractive force per car due to friction.	Empty. Tractive force per ton due to friction.	Empty. Percentage of weight.	Loaded. Weight of car.	Loaded. Tractive force per car.	Loaded. Tractive force due to gravity.	Loaded. Tractive force per car due to friction.	Loaded. Tractive force per ton due to friction.	Loaded. Percentage of weight.	No. of Tests. Empty.	No. of Tests. Loaded.
LEVEL.														
Average slow start	2240	100	....	100	100	4·46	8500	325	....	325	85	3·80	16	12
Average slow start	2140	83	....	83	$86\frac{9}{10}$	3·88	7885	357	....	357	$101\frac{4}{10}$	4·53	63	53
Average motion 50 feet per minute	2140	54	....	54	$56\frac{6}{10}$	2·52	7885	205	....	205	$58\frac{3}{10}$	2·60	54	60
Average motion 1000 feet per minute, 1 car	2140	62	....	62	$64\frac{2}{10}$	2·89	7885	262	....	262	$74\frac{4}{10}$	3·32	17	74
Average motion 1000 feet per minute, 4 cars	2240	$62\frac{1}{4}$	....	$62\frac{1}{4}$	$62\frac{1}{4}$	2·80							3	...
Average motion 1000 feet per minute, 20 cars	2240	47	....	47	47	2·20	9000	117	....	117	29	1·30	6	18
Average starting jerk, 20 cars	2240	96	....	96	96	4·29	9000	175	....	175	44	1·95	3	7
Average starting jerk, 2 cars, rope haul	2240	630	....	630	630	28·12							10	
GRADE.														
Average slow start 12°	2140	550	445	105	110	4·90	7885	1950	1639	311	$88\frac{4}{10}$	3·94	2	2
Average motion 50 feet per minute, 12°	2140	510	445	65	68	3·18	7885	1800	1639	161	$45\frac{8}{10}$	2·00	10	16
Average motion 1000 feet per minute, $1\frac{3}{4}$°, 1 car	2140	125	65	60	$62\frac{8}{10}$	2·80							10	
Average motion 1000 feet per minute, $1\frac{1}{2}$°, 1 car							7885	425	205	220	$62\frac{5}{10}$	2·79		12
Average motion 200 feet per minute, rope-haul, 2°	2240	140	78	62	62	2·80	Cars pulled from side.						15	
Average motion 200 feet per minute, rope-haul, 2° 30′	2240	183	98	85	85	3·80							15	
Average motion 200 feet per minute, rope-haul, 5° 10′	2240	315	202	113	113	5·00							15	
Average motion 200 feet per minute, rope-haul, 6° 10′	2240	353	240	113	113	5·00							15	
CURVE.														
Average slow start, 85 feet radius	2240	125	....	125	125	5·58	8500	400	....	400	106	4·70	10	10
Average slow start, 11 feet radius, $1\frac{1}{2}$° grade							8700	819	227	592	152	[illegible]·80		8
Average 20 cars, 1000 feet per minute, 350 feet radius	2240	62	....	62	62	2·80	9000	143	....	143	36	1·60	5	7
Average 20 cars, 1000 feet per minute, 450 feet radius	2240	50	....	50	50	2·23	9000	126	....	126	32	1·40	5	7
Average 4 cars, 1000 feet per minute, 350 feet radius	2240	100	....	100	100	4·46							2	
Total number of tests.													276	286

SUMMARY OF FRICTION-TESTS ON SUSQUEHANNA COAL CO.'S MINE-CARS, APRIL, 1889.—*Continued.*

DIMENSIONS OF WHEELS.

16 inches, diameter of thread.
2½ inches, diameter of axle.
5¼ inches, length of journal.

	New Style Wheels. Empty. Weight of car.	Empty. Tractive force per car.	Empty. Tractive force due to gravity.	Empty. Tractive force per car due to friction.	Empty. Tractive force per ton due to friction.	Empty. Percentage of weight.	Loaded. Weight of car.	Loaded. Tractive force per car.	Loaded. Tractive force due to gravity.	Loaded. Tractive force per car due to friction.	Loaded. Tractive force per ton due to friction.	Loaded. Percentage of weight.	No. of Tests. Empty.	No. of Tests. Loaded.
LEVEL.														
Average slow start	2415	66⅞	....	66⅞	62	2·78	9125	200	....	200	49	2·20	6	20
Average slow start	2415	62	....	62	$55\frac{6}{10}$	2·48	8160	193	....	193	53	2·36	82	48
Average motion 50 feet per minute	2415	40	....	40	$37\frac{1}{10}$	1·66	8160	133	....	133	$36\frac{5}{10}$	1·63	81	72
Average motion 1000 feet per minute, 1 car	2415	36⅞	...	36⅞	$33\frac{9}{10}$	1·48	8160	158	....	158	$43\frac{3}{10}$	1·93	6	39
Average motion 1000 feet per minute, 4 cars	2415	37⅛	....	37⅛	34⅞	1·56							6	...
Average motion 1000 feet per minute, 20 cars														
Average starting jerk, 20 cars														
Average starting jerk, 2 cars, rope haul														
GRADE.														
Average slow start 12°	2415	600	502	98	$90\frac{8}{10}$	4·06	8160	2000	1696	304	$83\frac{3}{10}$	3·73	2	2
Average motion 50 feet per minute, 12°	2415	540	502	38	$35\frac{1}{10}$	1·56	8160	1825	1696	129	$35\frac{8}{10}$	1·58	6	12
Average motion 1000 feet per minute, 1¾°, 1 car	2415	100	73	27	25	1·12	8160	400	249	151	$41\frac{5}{10}$	1·85	6	6
Average motion 1000 feet per minute, 1½°, 1 car							8160	350	212	138	$37\frac{2}{10}$	1·69		16
Average motion 200 feet per minute, rope-haul, 2°														
Average motion 200 feet per minute, rope-haul, 2° 30′														
Average motion 200 feet per minute, rope-haul, 5° 10′														
Average motion 200 feet per minute, rope-haul, 6° 10′														
CURVE.														
Average slow start, 85 feet radius							9125	275	....	275	67	3·00		8
Average slow start, 11 feet radius, 1½° grade							9125	564	239	325	80	3·60		7
Average 20 cars, 1000 feet per minute, 350 feet radius														
Average 20 cars, 1000 feet per minute, 450 feet radius														
Average 4 cars, 1000 feet per minute, 350 feet radius	2415	75	....	75	70	3·10							2	

In the experiments upon slow start and motion, the cars were started very slowly by a block and tackle, and the reading was taken at the moment of starting. They were then kept just moving along the track for a considerable distance, and the average tractive force was noted—the whole constituting one experiment.

The track selected for these experiments was a perfectly straight and level piece of 42 ins. gauge, about 200 ft. long, in rather better condition than the average mine-track. The cars were 41¾ ins. gauge, 3⅛ ft. wheel-base, 10 ft. long, capacity about 85 cubic ft., with 6 in. topping.

To ascertain the tractive force required at higher speeds, trips of 1, 4 and 20 cars, both empty and loaded, were attached to a mine-locomotive and run about a mile for each test, the resistance at various points on the track, where its curve and grade were known, being noted, and care being taken to run at a constant speed. Unfortunately, only four of the "new style" cars were available on the tracks where these trials were made.

The remarkable low results for the twenty-car trips are attributed to variations in the condition of the track, and the fact that the whole train was seldom pulling directly on the locomotive, the cars moving by jerks, so that correct observations were impracticable. The hydraulic gauge was used for these twenty-car tests, and the needle showed vibrations from one to four tons and back. The mean was taken as nearly as possible. The gauge was rather too quickly sensitive for the work, and the Pennsylvania Railroad dynamometer was not strong enough to stand the starting jerks and the strain of accelerating speed.

The tests marked "rope-haul" were made on an empty-car haulage system, about 500 ft. long, with overhead endless rope running continuously at a speed of 180 ft. per minute, the cars being attached to the moving rope by a chain, a ring at the end of which was slipped over a pin on the side of the car. The increase of friction on the heavier grades was due to the rope pulling at a greater angle across the car. Correction was not made for this angularity at the time, and the rope has since been re-arranged, so that the correction cannot now be made.

There were not enough curve-experiments to permit the deduction of any general formula for the resistance of these cars on curves.

The experiments on grade agree fairly well with those on a level, the rather higher values obtained being probably due more to the greater effort required in moving them and the consequent jerkiness of the motion than to any real increase in resistance. As the experiments on all styles of wheels were made in an exactly similar manner, the comparative value of the results is believed to be nearly correct, the probable error in each set of experiments, as computed by the method of least squares, varying from about 4% for slow start and motion to 12% for the rapid motion and twenty-car trips.

INCREASE OF TEMPERATURE IN DEEP MINES.

It has been generally accepted in the past that in mines the temperature increased 1° Fahr. for about every 65 feet of depth. Recent observations, however, prove that this does not hold good. In a bore hole at Schladebach, Germany, 5,630 ft. deep, the average increase in temperature was found to be 1° Fahr. for every 107·5 ft. In this bore hole, at a depth of 5,630 ft., almost the highest temperature observed in the interior of the earth, 134° Fahr., was recorded. At a depth of from 4,153 to 5,630 ft. the temperature rose one degree for every 115·24 ft. in depth.

COLLIERY MACHINERY.

By C. M. Percy, Mem. Inst. Mech. Eng., F. G. S., Wigan, Eng.

HOW THE ARTICLE CAME TO BE WRITTEN.

In the early part of the present year I was asked by some friends, who are directors of a large colliery employing several thousand men and boys, to establish a School of Mines in connection with the colliery, at which officials and workpeople could add to their practical experience some theoretical knowledge. I commended and inaugurated the new School of Mines with an address on *Colliery Machinery*. I selected that as a subject because all my life I have been closely identified with it, and for a quarter of a century have endeavored to give instruction in it. That address came under the notice of the publishers of this book and they wrote me suggesting an enlargement and rearrangement for the present purpose. They asked for an article which would explain the principles of and describe colliery machinery, such as steam engines, pumps, air compressors, mechanical ventilators, hauling plant, safety machinery, steam boilers, etc. etc., prepared in such a way as to be of service to a mining student or an experienced mining foreman, and at the same time meet the requirements of a youth or a man who might know nothing of colliery machinery till the article got into his hands. This suggestion almost reminded one of James Gordon Bennett's cablegram to H. M. Stanley, "*Find Livingstone*," but I fear the result will not be so successful as the termination of that memorable incident. However, I quite agree that many of our Engineering Treatises are of no avail to thousands of people thirsting for knowledge because they are too learned. I will endeavor to be plain and practical.

I do not propose to make any attempt at dealing exhaustively with such a far reaching subject; to do so successfully would occupy not an article merely, but a treatise. Many such elaborate and fully illustrated treatises have been written. and may with advantage be studied. I do propose to deal with the matter in a popular and easily understood manner so far as space will allow; to try and show the important part it plays and ought to play in mining operations; and to refer more or less fully to one or two sections of the subject.

IMPORTANCE OF MACHINERY IN MINING OPERATIONS.

Whatever skill may be expended in the opening out and the development of our coal mines, however safe the operations may be, without the powerful aid of machinery, mining instead of being one of the greatest of our national industries, providing occupation directly for thousands of people, and being the mainstay of other industries, would be a mere pettifogging means of employment.

We cannot fail to be impressed with the enormous strides which have been made during the present century. At its commencement we had a few shallow pits here and there, the coal was carried or dragged to the pit mouth by women and children, and on reaching the surface was conveyed across the country to rivers and seas on the backs of mules and ponies. But what do we see now? Gigantic winding engines, each of hundreds of horse power, manipulated by one man with the greatest ease, and raising tons of coal at each journey, with the speed of an express train; powerful pumping engines capable of dealing with seas of water; hauling machinery connected with all parts of the mine, and conveying with ease and rapidity the whole of the output from the working places to the cage; ventilating machinery passing through miles of underground workings, enormous volumes of air, the like of which our forefathers never dreamt, and which they would not have believed possible. Upon our pit banks we have elaborate and effective appliances for weighing every pound of coal. and for picking and cleaning and separating into any number of sizes. Then with our wonderful network of railways, intersecting and reintersecting the continent from north to south and east to west, bringing all our cities and towns and ports and villages into immediate communication, by means of our marvelous steam horse, we distribute our hundreds of thousands of tons of coal each day to places far distant, and within a short period of being actually worked in the mine. No part of the world has shown more progress in coal mining than America. A couple of generations ago it was a mere infant, now it is well developed and will ultimately become a herculean industry upon this continent. We introduce our subject in this way to prove at the outset, if proof be necessary. how important a position machinery occupies in colliery work, and to draw the moral that all managers and officials and workmen engaged in such work should know something of the various classes of colliery machinery and the principles upon which that machinery operates.

THE CHIEF MOTIVE POWER IS STEAM.

Now, first of all we ask ourselves the question : What is the almost universal power as now applied to colliery machinery ? And the answer is—steam. Although we have been hearing a good deal for twenty years, and are hearing a good deal now, to the effect that steam has had its day and must soon stand aside, we are bold enough to predict that so long as any person now living continues to live we shall have for colliery work nothing else so cheap and efficient as steam. And what is this steam ? George Stephenson, the great railway pioneer, was not far wide of the mark when he said it was "a bucket of water in a violent state of perspiration." Steam is water, which we can see, converted into an invisible gas, which we cannot see, and the conversion is effected by the application of heat, which imparts expansive power and elasticity to the steam. The so called steam which we do see is merely a visible vapor, something between steam and water.

WHAT IS HEAT ?

There is some difficulty in explaining as clearly as we could wish what this heat is. It is, perhaps, not generally understood that all bodies, whether gases such as the air we breathe, or liquids such as the water we drink, or the massive bars and plates of iron and steel of which such structures as the Forth Bridge are constructed, are all made up of atoms so small that no microscope can make them visible. These atoms never touch each other, are constantly whirling round each other, and are held in combination by the enormous force of cohesion. Heat at one time was believed to be a substance which surrounded these atoms. That idea is now abandoned, and the accepted scientific theory is that heat is motion, more or less rapid, of these atoms round each other. Sensible heat is heat perceptible to the touch ; latent heat is heat *not* sensible to the touch but absorbed in changing a liquid into a gas and giving to it elastic power. One unit of mechanical work is equal to raising one pound weight one foot high. One unit of heat is equal to 772 units of work. One unit of heat is the amount of heat required to raise the temperature of water one degree Fahrenheit.

WHAT IS COAL ?

There the question arises, how do we obtain this heat by which steam is generated ? and the answer is, by the burning of coal, a substance in which we are all specially interested, and the abundance of which has made England great. But what is coal, and how was it formed, and whence comes its great heat producing power ? Coal is a result of the primeval forests—the forests which existed ages and ages ago, and the rays of the sun acting upon the trees of those forests dissociated the oxygen, which was freed to purify the atmosphere, and the carbon, which was simply left. The numerous inundations and convulsions of early times which followed the early solidification of the earth's surface, covered these deposits of carbon with earthly matter. And our deposits of coal are simply the accumulation of energy derived from the sun. We now, perhaps millions of years afterwards, bring this coal to the surface, and uniting it with oxygen from the atmosphere, the combination taking place at a sufficiently high temperature, we produce an amount of heat representing the energy which the sun exercised in effecting the separation. One pound of average quality of coal possesses 12,000 units of heat and therefore equals $12{,}000 \times 772 = 9{,}264{,}000$ units of mechanical work.

THE SUN THE GREAT SOURCE OF POWER.

We do not sufficiently realize the important influence of the sun upon mechanical work. We have shown how our coal owes its power to the brilliant orb of day, but that is not nearly all. All the power of falling water, whether it be the gentle tributary or the roaring torrents of Niagara, is obtained from the same source. Under the sun's influence there is a constant evaporation from the surfaces of our oceans and seas and lakes and this vapor rises into cloudland, and being condensed comes back in the form of rain. Mountainous districts are peculiarly wet, because the hills and ridges and mountains form condensing surface, and so give us the torrents of falling water which feed our streams and brooks and rivers. Then, again, the wind, which may be either the calm and gentle breeze, or the storms and hurricanes which sweep with terrific force over land and sea, attains all its power from the sun acting upon some portions of the earth's surface at times more intensely than upon other parts, the atmosphere is heated and rarefied, and passing away to make room for colder air, the winds are produced.

HOW TO USE STEAM TO BEST ADVANTAGE.

We have then arrived at this point—that steam is our principal motive power in colliery work, and is simply water converted into gas by the action of heat produced in the burning of coal. What we have now to do is to show how that steam can be used to the best advantage. When we make a calculation of the power which coal possesses, and compare it with the useful work which steam engines exert, we are startled to find that probably in the very best engines not one-tenth of the power is transmitted as useful work, and in some very bad engines probably not one-hundredth. There are many causes for this, some we can never remedy, because to do so we should have to work steam down to a temperature near upon 500° F. below freezing point, which is quite impossible even approximately. There are other causes which can be removed, and which ought to be removed. We want good engines, good boilers, high pressure steam, expansive working, and condensing appliances.

ADVANTAGES OF HIGH PRESSURE STEAM.

Why should we use high pressure steam? There are several quite simple and emphatic reasons. Whatever pressure we have available at the steam boiler a certain amount is absorbed in overcoming the resistances of the engine and without doing any useful work. Suppose our available steam pressure is 20 lbs., and 10 lbs. are so absorbed, that leaves us only one-half; but if we have 100 lbs available it would leave us nine-tenths. High pressure steam means fewer boilers and smaller engines, with foundations and houses of less dimensions.

Then again, the amount of work which it is possible to get out of a given quantity of steam depends on the difference between the temperature at the commencement of the stroke and the temperature at the end of the stroke.

Now there is a limit as to how low the temperature can be at the end, and as we raise the commencing temperature we enlarge the available difference.

We may put the advantages of high pressure steam in this way. By taking a fixed temperature in the condenser of, say, 100° F., and initial temperatures when the steam enters the cylinder, of varying amounts, the theoretic efficiency of that steam can be determined.

Commencing with atmospheric pressure, we have an efficiency of 16·6 per cent.

Lbs.	Per cent.	Lbs.	Per cent.
10	20·0	100	29·8
20	22·1	125	31·1
30	23·7	150	32·2
40	25·0	200	33·9
50	26·1	250	35·3
60	27·0	300	36·5
80	28·6		

When we speak of so many degrees F. or °F we mean so many degrees according to the thermometer of Fahrenheit. Then about this percentage. We can only get in practice with steam a certain proportion of the theoretic power and that proportion varies with the pressure of the steam.

In early days we used steam at atmospheric pressure, the efficiency being 16·6 per cent.; afterwards we had in compound engines of two cylinders, steam of 60 lbs., the efficiency being 27 per cent. Now we have triple expansion engines, using steam at 150 lbs., the efficiency being 32·2 per cent. It will be observed that although the efficiency increases as the steam pressure increases, the amount of that increase is a diminishing quantity, and it becomes so small at and beyond 150 lbs. pressure that probably any gain in efficiency is not a satisfactory set off to the additional expense of strengthening the parts of the engine. But then, how very few of our engines work nearly so high as 150 lbs. pressure?

There is no class of steam engine which gives so much work from a given quantity of coal as the marine engine. We on land are wasteful, and at collieries especially wasteful, and throw coal under our boilers as if it were valueless; but every ton of coal on board ship means a ton of cargo less, and every ton of coal saved means another ton of cargo carried.

WHY USE STEAM EXPANSIVELY?

By this we mean that at a certain point of the stroke we shut off steam supply from the boiler to the cylinder, and the steam already within the cylinder performs the remainder of the stroke unaided.

Now, suppose we do not expand at all. Suppose we allow free admission of steam into the cylinder all through the stroke; we shall have at the end of the stroke pressure exactly similar to the pressure with which we commenced. Now we cannot work a seam of coal and still have the coal left; we cannot get work out of steam and still have the work left in it, and so if our steam pressure is the

same at the end of the stroke as at the beginning, we simply discharge twice in each revolution a whole cylinder full of steam which has done no work at all, and waste it just the same as if we had discharged it from the boiler without passing through the engine at all. But some one will say, work has been done upon the engine whilst that steam was in the cylinder. True—quite true, and the explanation is that, whilst the steam is performing work its heat and pressure must diminish, and so long as the communication with the boiler is open, fresh heat comes from the boiler into the cylinder to take its place, and at the end of the stroke we have expended heat represented by the capacity of two cylinders, and have performed work as represented by the capacity of one cylinder. Now, suppose we close the communication, and beyond a certain point of the stroke allow no more steam to enter, we get an amount of work from the steam already in the cylinder, represented by the diminishing pressure of the steam by expansion.

WHY USE CONDENSING APPLIANCES

We have said that condensing appliances are necessary ; what do we mean by this ?

The effective power of an engine does not depend upon, and is not measured by the pressure pushing the piston. We have always what we term a back pressure holding the piston back, and the real effective pressure is evidently the difference between the two. Suppose we have a locomotive engine, or a winding engine, throwing exhaust into the open air. The back pressure cannot be less than the pressure of the open air, and indeed to overcome it, it must be something more. But if we can discharge our exhaust into some vessel, from which atmospheric pressure and all other pressure has been removed, we know that atmospheric pressure amounts to about 15 lb., and the removal of that from the front of the piston is as good as adding 15 lb. behind.

In this matter of condensing appliances, we have at collieries progressed backwards. I do not know of any very modern winding engines, utilizing the benefits of a vacuum, and am free to confess that the cumbersome mechanism which constitutes the condensing element in the older class of engines would be unsuitable, and further that the increasingly high pressure and high speed, together with low ratio of expansion, are not favorable to effective condensation. But greater difficulties than these have been overcome, and the object to be accomplished is so important that all these difficulties *ought* to be overcome, and *will* be overcome.

WHAT IS A GOOD STEAM BOILER ?

The colliery boiler, which finds much favor, and of which I have a very high opinion, is the Lancashire boiler. I mean the class of boiler which is 28 or 30 feet long and 7 or 8 feet diameter and has two large flues running through. There is no doubt that the marine type will generate more steam with a given amount of coal, and consequently is gaining ground and will gain ground where coal is dear. But the Lancashire boiler is a good steam generator, and will not only work longer without repairs, but is less troublesome and expensive to repair. The favorite construction some few years ago was wrought iron with double riveted horizontal joints, and Galloway tubes, [Galloway tubes are simply taper tubes running across the flues in the boiler] and expansion weldless hoops strengthening the flues and allowing for expansion and contraction. The dimensions were 7 ft. diameter, and from 28 to 30 ft. long, with internal flues each 2 ft. 9 in. diameter, the circular plates being about ½ in., and the end plates about ⅝ in. The safe working pressure was about 60 lb. per square inch. Now the conditions are somewhat altered. Steel has taken the place of iron, giving increased strength, and allowed increased diameter and increased pressure. Ring plates also have abolished a great source of weakness in a boiler, namely, horizontal riveted joints. [By ring plates I do not mean jointless rings but rings with only one butt joint with planed edges.] Expansion hoops upon the flues remain as before, and Galloway tubes ; these latter increase the heating surface, improve the circulation, and compel the heated gases to act more upon the plates of the flues. A good Lancashire boiler now will measure 8 ft. in diameter, and 30 ft. long, with ring plates ⅝ in. thick. End plates probably ¾ in., and will work very well at 120 lb. pressure per square inch.

In the matter of calculations as to horse power of steam boilers, been to me a cause of considerable difficulty. My friend, Mr. Fletcher, an eminent authority and long identified in good work chester, England, Steam Users' Association, said a Lancashire 28 ft. by 7 ft. was capable of generating steam for 200 horse

Many of my friends consider that in quoting this I was accepting an over estimate. Another equally eniment authority upon steam boilers says we ought to reckon the horse power of a boiler by the quantity of water it will evaporate. With a moderate good engine half a cubic foot of water, or about 30 lb., will develop one indicated horse power per hour. With internally fixed boilers having the proportion between heating surface and grate area between the limits of 10 and 16 to 1, the evaporative capacity may be taken at 1 cubic foot, from 18 square feet of heating surface, or 9 square feet of heating surface per horse power. Well, now, a Lancashire boiler such as Mr. Lavington Fletcher described, would not have more than 900 square feet of heating surface. and, according to this rule, would only be equal to 100 horse power. A modern Lancashire boiler such as I have described will scarcely have more than 1,000 square feet of heating surface, although measuring 30 ft. by 8 ft., and, according to Mr. Wilson's rule, [Robert Wilson on Steam Boilers] would not be equal to more than 111 horse power, being an increase of 11 per cent. in horse power, and probably 30 per cent. in capacity. In another rule Mr. Wilson takes for Lancashire boilers 7 square feet of heating surface per horse power, instead of 9, and so increases our figures to 130 and about 142. But I see an announcement by an eminent firm, who are no novices at boiler engineering, that three of their boilers, measuring each 30 ft. by 7 ft., are actually driving near upon 1,600 horse power, say, 500 each. Now, in the face of such contradictory statements as these and all from deservedly high authorities, who is to step in and decide? It does appear to me that if we compare Mr. Lavington Fletcher's estimate of 200 horse power for boilers working 60 lb., and measuring 28 ft. by 7 ft. with the statement of fact that each boiler, measuring 30 ft. by 8 ft., and working at, I suppose, about 120 lb., is actually working over 500 horse power, we shall find a similarity, and would be led to accept Mr. Lavington Fletcher's estimate, and increase the horse power of Lancashire boilers on that estimate as the pressure increases, and also as the capacity increases. I cannot venture to suggest a hard and fast rule, but the above conclusion is at least as likely to be correct as the so called rules we have quoted.

We must always remember in dealing with the horse power of boilers that the power of engine, which they will drive depends upon the engine. A good steam engine at high pressure, working compound, that is using the same steam successively in more than one cylinder, and condensing, and expansively discharging steam at a very low pressure, will generate very much more power with the same amount of steam, than an ordinary colliery engine which discharges its steam at a high pressure. A really good steam boiler will evaporate 10 pounds of water into steam with one pound of coal, and a good engine will generate continuously one horse power for an hour with 20 pounds of steam. A good boiler measuring 28 ft. long and 7 ft. diameter will evaporate 6,000 pounds of water in an hour and equal 300 horse power in a really good engine. A good boiler measuring 30 ft. long and 8 ft. diameter will evaporate 8,000 pounds of water in an hour and equal 400 horse power.

The equipment of a good Lancashire boiler may be taken as follows:—To be fixed absolutely level on a seating of which nothing but firebrick or fireclay shall come in contact with plates; flues so arranged that no heated gases can operate above water line; gases to pass through the internal flues, then return under the boiler, then split along both sides of boiler and pass to chimney. Firegrates and firedoors with adjustable air grids, feed valve and feed pipe to prevent water leaking out of boiler and admit only hot water as spray, injecting upwards from horizontal pipe a little below water line. Steam junction and horizontal steam pipe high up in the boiler and pipe having no perforations except on upper side. Two safety valves—one dead weight, and one low-water; two water-gauge glasses, one steam-gauge, one scum tap and pipe; one blow-off tap, two manholes; expansion rings in the internal flues to allow for expansion and contraction. The needful dampers and covering to boiler externally. I have practically no faith in boiler compositions; where they benefit the boiler I believe that they injure the cylinder and the valves. Every steam boiler should be cleaned as often as the accumulation of dirt may prove to be necessary, and all internal scurf and scale carefully removed.

The advantages of high-pressure steam are not yet sufficiently appreciated. It is not merely the difference between 60 lb. and 120 lb. Suppose we use steam at 60 lb.; probably we shall get 50 lb. at engine, and resistances of engine will absorb 10 lb. leaving 40 lb. Now suppose we use 120 lb., we can get at engine 110 lb., and if resistances of engine absorb 10 lb., we shall have 100 lb. as against 40 lb.

How do we arrive at safe working strength of a Lancashire boiler with ring seams and steel plates?

We assume a ring one inch long. Good boiler-plate steel should have tensile strength of at least 30 tons=67,200 lb. per square inch ÷ 6 for safe working strength=11,200 lb. Then suppose plates ¾ in. thick—11,200 × ¾ × 2 = 14,000 ÷ 96 in. the diameter of boiler=near upon 146 lb. per square inch safe working pressure when new. If there were no ring plates and the horizontal seams were double-riveted we should deduct one-fourth, making safe working pressure 108 lb. We always calculate the strength of a boiler in the direction of its diameter because, theoretically, a boiler is twice as strong in the direction of length as direction of diameter. Many causes may bring about boiler explosions. First, bad materials; second, bad workmanship; third, bad water, which eats away the plates by internal corrosion; fourth, water lying upon plates, bringing about external corrosion; fifth, over-pressure; sixth, safety valves sticking; seventh, water getting too low; eighth, excessive firing; ninth, hot gases acting on plates above water level; tenth, choking of feed pipes; eleventh, insufficient provision for expansion and contraction; twelfth, insufficient steam room and too sudden a withdrawal of a large quantity of steam; thirteenth, getting up steam, or knocking off a boiler too suddenly; fourteenth, allowing wet ashes to lie in contact with plates. The probable causes suggest their several remedies.

Before leaving the subject of the steam boiler, I would wish to say that wherever possible, and except under certain circumstances to be afterwards mentioned, steam engines should not be placed in the mine, and certainly steam boilers should be in all cases placed upon the surface. Steam injures the ventilation, increasing the temperature where already too high, doing injury and causing inconvenience by condensation, and many fires in mines have been caused by underground boilers.

WHAT IS A GOOD STEAM ENGINE?

It should be as direct-acting as possible; that is, the connecting parts between the piston and the crank shaft should be few in number, as each part wastes some power. Formerly beam engines were all the rage. They were well enough in their time for pumping, when the pump was at one end of the beam and the piston at the other, and so our early steam engines were all beam engines. There is a story told of an eminent Japanese who was resident for some time in England, and who was desirous of marrying an Englishwoman. He was on friendly terms with an English nobleman, to whom he put the question one day, "How did you obtain Lady ——'s consent to be your wife?" "Well," said my lord, "do you know that I proposed and was accepted under an umbrella?" Our Japanese friend jumped to the conclusion that the umbrella was a necessary part of the proceeding, and not long afterwards, meeting the mistress of his heart in the entrance hall of another acquaintance, he snatched an umbrella from the stand, raised it over the astonished fair one's head, and popped the question. Let us hope he was successful. Early steam engine makers considered beams as essential in engines as the Japanese thought umbrellas were in offers in marriage; and, as a matter of fact, the one is about as essential as the other, and now both are usually dispensed with. Few of our modern colliery engines have such an appendage, except in some instances for pumping, and even for that kind of work there are better engines without beams than with. The moving parts of an engine should be strong to resist strains, and light, so as to offer no undue resistance to motion, parts moving upon each other should be well and truly and smoothly finished to reduce resistances to a minimum, the steam should get into the cylinder easily at the proper time, and the exhaust should leave the cylinder as exactly and as easily. The steam pipes supplying steam should have an area one-tenth the combined areas of the cylinders they supply, and exhaust pipes should be somewhat larger. The cylinder and the steam pipes and the boiler should be well protected. The engine should be capable of being started and stopped and reversed easily and quickly. The crank and connecting rod is a beautifully simple mechanism, generally applied to engines. It converts straight line motion into circular motion; it exactly determines the length of the stroke; it effects an easy reversal of the movement of the piston twice in each revolution. The fly-wheel works with the crank and connecting rod, and is a needful adjunct. When a crank is on what we term dead-centre twice in each revolution it possesses no turning power at all, and when it is on mid-centre twice in each revolution it possesses full turning power. The result would be a rush and a jerk over mid-centre and a sticking on dead-centre. The fly-wheel comes to the rescue, and whilst it can add no power to an engine it can equalize that power, taking some up when excessive, and giving it back when deficient, thus producing a uniform amount of turning power all though the revolution. We

may liken its action to a banking account. A man sometimes has more money on hand than he wants ; he is then on mid-centre, and puts the surplus power in the bank. Then he gets on dead-centre, and wants a little turning power to help him over, and he draws it from the bank.

THE STEAM ENGINE.

To find the indicated horse power of a steam engine.—H. P. = Twice the area of the piston in square inches, multiplied by the average pressure of steam per square inch in cylinder, multiplied by the number of revolutions per minute, multiplied by the length of stroke in feet, and the product divided by 33,000.

TABLE OF STEAM USED EXPANSIVELY.

Initial Pressure in lbs. per sq. in.	Average Pressure of Steam in lbs. per sq. in. for the whole stroke.					
	Portion of stroke at which steam is cut off.					
	¾	⅝	½	⅜	¼	⅛
5	4·8	4·6	4·2	3·7	2·9	1·9
10	9·6	9·1	8·4	7·4	5·9	3·8
15	14·4	13·7	12·7	11·1	8·9	5·7
20	19·2	18·3	16·9	14·8	11·9	7·6
25	24·1	22·9	21·1	18·5	14·9	9·5
30	28·9	27·5	25·4	22·2	17·9	11·5
35	33·8	32·1	29·6	25·9	20·8	13·4
40	37·5	36·7	33·8	29·6	23·8	15·4
45	43·4	41·3	38·1	33·3	26·8	17·3
50	48·2	45·9	42·3	37·0	29·8	19·2
60	57·8	55·1	50·7	44·5	35·7	23·1
70	67·4	64·3	59·2	52·4	41·7	26·9
80	77·1	73·5	67·7	59·3	47·7	30·8
90	86·7	82·6	76·1	66·7	53·6	34·6
100	96·3	91·8	84·6	74·1	59·6	38·4
110	106·0	101·0	93·1	81·5	65·6	42·5
120	115·2	110·2	101·5	89·4	71·5	46·1
130	125·4	119·1	110·0	95·3	77·5	50·0
140	134·9	128·6	118·5	103·8	83·3	53·8
150	144·7	137·8	126·4	111·2	89·4	57·7
160	153·6	147·0	135·4	118·2	95·4	61·5
180	173·7	164·6	152·3	132·9	107·3	69·2
200	192·7	183·7	169·3	148·3	119·3	76·9

Let A = Area of piston in square inches.
" D = Diameter of piston in inches.
" P = Average pressure of steam in lbs. per sq. in. in cylinder.
" S = Length of stroke in feet.
" R = Number of revolutions per minute.

$$\text{Then, indicated H. P.} = \frac{2\,A\,P\,R\,S}{33{,}000}$$

EXAMPLE.—Find the indicated horse power of an engine having a 10 in. cylinder, 3 ft. stroke, steam cut off at ¾, running at a speed of 100 revolutions per minute, initial pressure or pressure at steam gauge being 45 lbs. In this case

A = 78·54 sq. in., or area of circle 10″ diam.
P = 43·4
R = 100
S = 3

$$\text{Then } \frac{2 \times 78{\cdot}54 \times 43{\cdot}4 \times 100 \times 3}{33{,}000} = \text{indicated horse power.}$$

$2 \times 78{\cdot}54 \times 43{\cdot}4 \times 100 \times 3 = 2{,}045{,}181{\cdot}62$
$2{,}045{,}181{\cdot}62 \div 33{,}000 = 62$ — H. P.

This is approximately correct for high pressure engines.
The actual horse power will be from 5% to 15% less than this.

The only way in which the *absolutely correct* horse power of an engine can be obtained is by the use of a dynamometer. For practical work, however, the above is close enough.

"Nominal horse power" is fast becoming an obsolete expression. It expresses no definite size. To describe an engine, give the diameter of cylinder and length of stroke.

AIR-COMPRESSING ENGINES.

The question of compressed air arises, and had better be dealt with at once. In what we may consider its most modern and best arrangement, an air-compressing engine is a horizontal steam engine, with the piston rod prolonged backwards and an air cylinder placed behind the steam cylinder, with an air piston on the steam cylinder piston rod. The air cylinder has at each end inlet valves to admit air from the atmosphere, and outlet valves to allow air when compressed to pass from the air cylinder into the receiver. The actual compression of air is very simple; the inlet valves behind the piston open immediately the piston commences to move, and fills, or allows to be filled, the air cylinder with air at atmospheric pressure, say, 15 lb. per square inch in terms of absolute pressure. Upon the return stroke of the piston the inlet valves in front, close, and as the air within the cylinder cannot get away, the advancing piston compresses it until the required pressure is reached, when the outlet valves open and the compressed air passes into the receiver, to be afterwards conveyed in pipes as may be required.

Experience has shown that probably the most suitable pressure of compressed air for colliery purposes is 45 lb. per square inch ordinary, or in terms of absolute pressure, 60 lb. Now, if we could get as much power out of compressed air as is exerted in compressing it (*minus*, of course, resistances of machinery, &c.), we should have ready to our hands a safe and efficient means of transmitting power. But we cannot—at any rate, we do not. Why? In compressing air we generate and liberate heat—so much so that the air cylinder, if not surrounded with water, would become red-hot. The water absorbs some of the liberated heat, and heat being work, all heat thus absorbed is power lost. Then, again, this liberated heat acts upon the air which is being compressed, and has such an influence that air which, at the end of the piston stroke, in its compressed state should be, say, 2 cubic feet, is actually, at 60 lb. absolute pressure, 3 cubic feet, which, however, on passing to receiver, becomes only 2 cubic feet. We have exerted power to compress 3 cubic feet and have only power in 2 cubic feet; and we have all the loss as represented by heat absorbed in water surrounding the cylinder. These are enormous losses, practical remedies for which have yet to be discovered. The principal remedies suggested so far are, first cold water spray, playing upon the air within the air cylinder during compression; second, a wash of cold water on each side of the air piston. These are remedies in so far as they prevent the liberated and generated heat expanding the air, but they do not prevent the loss of the heat which they absorb. When we hear or read the term absolute temperature, it means ordinary temperature plus 460 because absolute zero is 460° F. below ordinary zero. Absolute pressure means ordinary pressure plus the atmosphere or 15 pounds.

However expensive, there are cases in which compressed air is invaluable, and the following points are worthy of attention. Air-compressing engines should work in couples at right angles; stroke not less than twice the diameter of air cylinder; maximum pressure 60 to 70 lb. per square inch absolute; speed of piston, 250 ft. per minute; inlet and outlet valves which open and close easily and quickly and correctly; receiver capacity the larger the better, close to air-compressing engines, and a minimum of ten times the capacity of air cylinder; means at bottom of every receiver to allow discharge of water; large and short exhaust passages in working cylinders to allow free discharge and prevent choking with ice; capacious pipes. These latter are very important, because friction of air increases as the square of the velocity and the efficiency of compressed air in passages and pipes is almost inversely as diameter. The clearance capacity at ends of air cylinder should be reduced to a minimum. Air-compressors should have a sufficiently powerful, that is, massive, fly-wheel.

Our readers will have observed that whereas, at the air cylinder, when compression is performed, the cylinder becomes very hot, and the water surrounding it will boil; at the hauling and pumping engine where the compressed air is used, ice and snow will be formed. The one phenomenon explains the other. We drive out the heat by compression in the one case, and in the other case during expansion, we want it back again, and, failing to get it, our temperature will fall even below freezing point.

An important point where compressed air is used should not be overlooked—that even in its conveyance the efficiency is diminished practically as the diameter is diminished, which means, of course, that our pipes should be as large as conveniently practicable, with commodious receivers adjoining the air-compressors, and each engine driven by compressed air.

We can all easily understand that in a long range of pipes, especially if small there is a very great amount of friction, especially if, as it must do in small pipes, the air travels very quickly. But with plenty of power at the air-compressing engines and good sized pipes so that the air does not need to travel very quickly we can retain a good pressure. There were pipes in the Mount Cenis Tunnel over a mile long and 7½ inches diameter and the pressure only fell from 85 to 82 pounds.

PUMPING MACHINERY.

We are not all agreed as to whether our forefathers were right with regard to Cornish pumping engines, or whether our more modern engineers are correct in applying so extensively the underground steam pump. No doubt for dealing with very great quantities of water, and without fear of drowning the pump, the Cornish arrangement, with massive beam, answers well enough, but in our opinion, it is at best a cumbersome structure, requiring massive foundations, occupies an inconvenient position, and is liable to serious mishaps. A much more effective form of pumping engine, even to be placed upon the surface, is the compound condensing differential engine of Davey, which does not stand towering above the pit shaft, does not require massive foundations, has a double range of pump rods with pump attached to each, exercising double action, and having a beautiful valve arrangement, which, should the pump make a mis-stroke, and the engine thereby incline to run away, reverses the engine and puts the steam in front until the engine resumes its normal speed. This pumping engine can either be placed upon the surface and connected with the pumps by means of long ranges of rods, or it can be placed underground, and so dispense with rods. An underground pumping engine of similar dimensions will do more work than a pumping engine placed upon the surface. I would like to try and make plain here what is meant by the term suction, on which all pumps so much depend. For many centuries before the Christian era pumps were used, although probably those who used them did not know why water rose to a pump. They said it was because nature abhorred a vacuum. But why did nature abhor a vacuum?

In the middle ages Torricelli, an eminent Italian philosopher, and pupil of a still more eminent philosopher, Galileo, was consulted about a pump in one of the royal gardens, to which the water refused to rise. Torricelli found that the height from the water to the pump was greater than in any previous case, and the idea occurred to him that nature's abhorrence to a vacuum simply meant the pressure of the atmosphere caused by the weight of the ocean of air surrounding the earth. If that were so, the height to which water or any other liquid would rise under the influence of that pressure would be less upon the top of a mountain than at the foot, because as we ascend the height, the weight of air above us becomes less. Torricelli constructed the barometer and made his experiments, and to his delight found that the mercury in the barometer stood higher at the foot of the mountain than at the top, showing that the sole influence under which water rose to a pump was atmospheric pressure, and the height to which it would rise was directly as the amount of that pressure. He lowered the pump in the well of the Royal gardens, and it worked all right.

What we now know is that the pressure of the atmosphere at the surface of the earth is about 15 lb. per square inch—that is, the same pressure as a vertical column of water 34 ft. high—and if we could exhaust all the air from a long range of pipes, water under atmospheric pressure would rise in the pipes to a height of 34 ft.

We place our pump in a certain position, and the suction pipes dip down into the water. We pump the air out of these pipes, and the water rises; not to a height of 34 ft., because whatever we do we cannot get all the air out, but the water rises something less than 34 ft. In practice it is well so to fix our pump that the maximun height of suction will not exceed 21 ft., and the nearer the pump is to the water, the better it will work.

Whilst generally against steam in mines, I am very partial to steam pumps at the bottom of shafts, and my idea of a good pumping plant is a pair of direct double-acting vertical or horizontal engines supplied with condensers and having a fly-wheel motion. Long pump rods are dispensed with and a comparatively small pumping arrangement, occupying little space, can do a great deal of work.

Suppose we had a pair of such pumping engines with 20 in. cylinders and 10 in. pumps, running 200 ft. a minute, and having available average effective steam pressure, with or without vacuum, of 50 lb. per square inch. How much water would they raise per hour, and to what vertical height?

First, as to quantity. The area of 10 in. diameter, 10 × 10 × ·7854 = 78½ square inches. We take 276 cubic inches of water as representing one gallon. 78½ × 12 = 942 cubic inches in each foot of pump × 200 = 188,400 cubic inches per minute × 60 = 11,304,000 cubic inches in an hour ÷ 276 = 40,956 gallons an hour—5 per cent. for slip of pump, leaves 38,908 gallons for each pump × 2 = 77,816 gallons an hour for the pair.

Secondly, as to height. We take 15 lb. per square inch as equal to 34 ft. vertical of water column. The piston is 20 in. diameter = 20 × 20 × ·7854 = 314 square inches area. The average effective pressure of steam is 50 lb. 314 × 50 = 15,700 lb. total pressure upon piston, and consequently upon pump. Now this total pressure, 15,700 ÷ area of pump, 78½ = 200 lb. per square inch upon the pump. Then, 200 × 34 = 6,800 ÷ 15 = 453 ft., the theoretic vertical height, from which in practice we shall do well to deduct one-third for resistances, leaving 302 ft. lift and 77,816 gallons of water per hour.

Now let us reverse the problem and proceed. Suppose we want to raise 50,000 gallons of water in an hour from a vertical depth of 600 ft. with a pair of direct double-acting steam pumps with available average steam pressure effective of 40 lb. per square inch, the pumps to work 200 ft. per minute, find size of pumps and of pistons.

First, the size of pumps. 50,000 gallons an hour × 276 = 13,800,000 cubic inches, ÷ 60 = 230,000 cubic inches per minute, ÷ 200 = 1,150 cubic inches per foot of pump, ÷ 12 = 96 square inches area of both pumps ÷ 2 = 48 square inches area of each. And the square root of (48 ÷ ·7854) = 7¾, say 8 in. diameter of pump. This assumption of 8 in. will make an allowance for slip of pump.

Secondly, as to size of piston. The area of 8 in diameter is 50·265. What is the pressure per square inch of 600 ft. vertical water column? 600 × 15 = 9,000 ÷ 34 = 264 lb. per square inch × 50·265 = 13,270 lb. total pressure on pump. The average effective pressure of steam is 40 lb. per square inch. Therefore 13,270 ÷ 40 = 332 square inches theoretic air of piston, to which in practice we should add one-half for resistances. 332 + 166 = 498 square inches area of piston. The square root of (498 ÷ ·7854) = 25¼ in. diameter of each piston and 8 in. diameter of each pump. It will be observed that having ascertained the theoretic power to do a given amount of work we add one-half for resistances, whereas when we determine the amount of work which an engine of given dimensions will perform we deduct one-third from its theoretic power. This is quite right and is explained very simply. Two *plus* one-half is three, and three *minus* one-third is two. Wherever we speak of average effective pressure of steam we mean that we deduct the average back or exhaust pressure from the average steam or forward pressure. We may roughly take the average effective pressure as two-thirds of the pressure shown upon the gauge close to the engine.

Either one of a pair of pumping engines should be equal, detached, to all the work to be done, and there should be lodge room for all the water that will be made in a week. The pump speed should not exceed 200 ft. per minute.

Pipes should be at least as large as the pump. Pipes are nearly always made too thick. They should be cast vertically so as to produce uniform thickness, and if so a pipe 12 in. diameter and ½ in. thick will safely work at a pressure of 233 lb. per square inch, being equal to 530 ft. of vertical water-column. Pipes decrease in strength as diameter increases, and the strength increases with the thickness. Some allowance will have to be made for stability of pipe and wear and tear, otherwise for low pressures our rule would only provide a very fragile structure.

Air vessels at the bottom of delivery pipes are of much service for breaking the shock and forming an air-cushion on the reversal of stroke, especially in single-acting pumps. When the suction pipes run inclined or horizontal for any considerable distance, air vessels are found effective upon suction ranges.

Pump valves are of many kinds; in open lifts in pit-shafts we use frequently "flap" or "hinge" or "butterfly" clacks. They answer fairly well for water not clean, and are easily renewed. For low lifts and moderate lifts we can use with advantage india-rubber "disc" valves. For small pumps we generally have "single beat" valves, similar to those in use for safety valves of the lever type. The best valve is the Cornish valve or "double beat" or "equilibrium" valve, which opens easily and for a small lift affords a considerable opening. The pumps themselves may be either buckets, with clacks within them, solid rams or plungers, or pistons.

The exhaust steam from pumps in mines may be, and is, very effectually prevented being a nuisance by being turned into the suction pipes. For effective condensation we require from 25 to 30 pounds of condensing water for each pound of exhaust.

It may be useful in calculations as to pumps and pipes to mention the quantity of water in a lineal foot of pipes of different sizes, and the quantity of water which pumps of those sizes will deliver per lineal foot.

	Gallons.		Gallons.
1 inch diameter	0·034	9 inches diameter	2·76
2 "	0·136	10 "	3·4
3 "	0·30	11 "	4·13
4 "	0·54	12 "	5·0
5 "	0·85	15 "	7·68
6 "	1·23	18 "	11·0
7 "	1·67	21 "	15·0
8 "	2·18	24 "	19·66

Perhaps it will be no work to put these figures approximately, also in more easily understood form:

1 inch, $\frac{1}{30}$ of a gallon.	9 inches, $2\frac{3}{4}$ gallons.
2 " $\frac{1}{7}$ " "	10 " $3\frac{1}{2}$ "
3 " $\frac{3}{10}$ " "	11 " $4\frac{1}{8}$ "
4 " $\frac{1}{2}$ " "	12 " 5 "
5 " $\frac{6}{7}$ " "	15 " $7\frac{2}{3}$ "
6 " $1\frac{1}{4}$ gallons.	18 " 11 "
7 " $1\frac{2}{3}$ "	21 " 15 "
8 " $2\frac{1}{5}$ "	24 " 20 "

10 pounds of water equals 1 gallon.
276 cubic inches of water equals 1 gallon.
1 cubic foot of water equals $6\frac{1}{4}$ gallons.
1 cubic foot of water weighs $62\frac{1}{2}$ pounds.
1 cubic inch of water at atmospheric pressure will evaporate into 1,644 cubic inches of steam at the same pressure.

The rule is, area of pipe or pump in square inches $\times$ 12 and $\div$ 276 = gallons of water per lineal foot. A deduction of 5 per cent. should be made for slip of pump.

THE SIPHON.

In close alliance with the pump is the siphon, which is an appliance needing no mechanical power, and which cannot raise water from a lower level and place it permanently upon a higher level, but can remove water from a higher level to a lower level, and pass it in transit over ground higher than either. It is in its simplest form a bent tube with legs of different length and looking down.

We cannot here deal with the principle of the siphon [except to say that the same atmospheric pressure which forces water up the suction pipe of a pump, forces water up the shorter leg of the siphon]; we can with its application. The level of delivery must be lower than level of entry. The highest point of siphon must not in theory reach 34 ft. above level of feed; in practice 21 ft. is a good deal, and the less the vertical height the better it will work. The siphon should be as free from bends and crooks and turns as possible, otherwise air will lodge. The pipes and joints must be tight. There must be a branch at the highest point to allow exit of air, and for charging with water. There should be a tap at delivery end and a self-acting clack at the feed end.

Now, as to flow of water from a siphon, theoretically, I assume in practice the maximum effective height to which water will rise in a siphon to be 21 ft. That determines the maximum effective fall, from which we can calculate the theoretic outflow of water. The effective fall will always be the vertical depth of delivery below the feed, provided that the depth and the vertical height, highest point of siphon above the feed, do not exceed 21 feet. When they do, the effective fall will be the difference between vertical height of the highest point above the feed and 21 feet. Having the effective fall, the velocity and quantity of water are not difficult to calculate. Take the effective fall in feet $\times$ 64; the square root of result is velocity of water in feet per second, theoretically, with which the water will flow out; in practice it will be something less. Suppose we have a siphon 2 in. diameter = 3·1416 square inches area, and an effectual fall of 10 ft., 10 $\times$ 64 = 640, the square root of which is 25 ft. per

second × 3·1416 = 78·6400 × 12 = 943·6800 cubic inches of water per second ÷ 276 = 3·4 gallons per second × 60 = 204·0 gallons per minute × 60 = 12,240·0 gallons of water per hour.

The rule and calculation as made above are purely theoretic, and make no allowance for friction, which depends upon length and diameter of siphon. It is evident that in practice a good deal will depend upon length and diameter, and a very eminent authority, Mr. Hawksley, has laid down the rule that the effective fall in feet divided by length of siphon in feet, the result multiplied by diameter of siphon in feet; the square root of all this multiplied by 48 will give us the velocity in feet per second, with which in practice water will flow out of a siphon. Having the velocity in feet per second, and knowing the area of the siphon, we can determine the quantity in gallons, as shown in the immediately preceding calculation.

We ought, perhaps, to have explained that if we take the height, the vertical height through which water or anything else falls and multiply by 64, which is twice the force of gravitation, the square root of the result will give us the velocity in feet per second at the bottom.

HYDRAULIC ENGINES.

These are now used at some collieries; they raise water by means of water power, and pump back the power water also. They are of great service in dip workings for raising water from these workings into the sump with which the main pumping engine is connected. We connect the hydraulic engines with the pipes of the main pump, and so get a very high pressure, which enables a comparatively small amount of water to pump a considerable quantity out of dip workings and to pump the power water also, thus avoiding the nuisance and inconvenience of steam

HAULING ARRANGEMENTS.

It is of the highest importance that for efficient and economical working a colliery should have a good system of haulage. Those mines which are formed like a basin, with the pit shaft at the center, and the descent sufficient to work by gravitation, leave nothing to be desired, and their owners and managers need no advice; they have our congratulations. But most mines are not so; they are irregular in their gradients, and require mechanical power to draw loaded tubs out and to draw empty tubs in. We say mechanical power, because it is a very poor arrangement of machinery which is not very much more effective in haulage than animals or men.

What kind of mechanical power shall we have? I say, unhesitatingly, steam. There is nothing, as yet, so cheap—nothing, as yet, so effective.

Friction is the great resistance, except in cases where we have a severe inclination from the pit, and it will not be out of place here to explain what we mean by friction. It is the resistance which one surface offers to another passing over it, and, in the case of liquids like water, and gases such as steam and air, increases with the amount of surface and increases also with the square of the velocity. With solid bodies it depends upon the weight and the distance traversed. To lessen the friction of tubs we should have axles as small as is consistent with safety, with journals as round and smooth as they can be made; wheels as large and as round as convenience and construction will allow. The friction of the ropes can be reduced by having them strong and light; also, by having a sufficient number, or, in other words, an abundance of well made and easy working rollers and pulleys. We prefer these of cast steel, as they are better made, lighter, stronger, and wear almost for ever. Hauling ropes should on no account be allowed to run on the floor or roof or sides of the mine; the friction thus occasioned is enormous, and the wear upon the ropes themselves very great indeed.

Where shall we place our steam engines? I, of course, advise on the surface. It is a good many years now since I expressed my individual opinion in favor of placing hauling engines upon the surface, and am more than pleased now to know that public mining opinion is growing fast in that direction. One difficulty formerly raised was that for deep mines, say 700 and 800 yards deep, the weight of the rope hanging in the pit shaft would be so enormous that such weight alone would be a very heavy load and almost as much as the rope would bear, and thus leave no strength for the actual haulage. But the material of which ropes are now made is so much improved that we have an enormous strength without necessarily having a heavy rope. Take a rope of plough steel, 1 in. diameter, and weighing 4 lb. a yard, 800 yards long would not weigh 1½ tons, and the breaking strain would be 40 tons.

Then, what method of haulage should be adopted? I strongly advocate the endless rope. It can be taken practically anywhere, round curves, along the level, up or down gradients, and can work any number of branches together or separately. It enables a comparatively slow motion and ensures continuous delivery of loaded tubs at the pit bottom and empty tubs in the workings. We can have any speed—one mile, two miles, three miles an hour; the engine piston speed should be 250 ft. per minute, and between the engine and the driving pulley we must have the needful spur gearing. The rope may be at side of tubs, or over the tubs, or under the tubs; the latter is probably the most efficient, as we can more easily, by means of vertical rollers between the rails, adapt the rope to any curve. Taking the wheels as about 10 to 12 in. and the axles 1 in. to 1⅛ in. and an average road, I allow for friction $\frac{1}{28}$ of the entire weight of rope, tubs and coal. If the wheels are larger the friction will be less; if the axles are larger the friction will be greater. On a level road this friction is the entire load; on a gradient falling to the pit bottom we have the tubs and coal, divided by gradient, in favor of load and deducted from friction. If the load of tubs and coal be 10 tons and gradient falling 1 in 10, then $10 \div 10 = 1$ ton to be deducted from the friction. If the gradient falls from pit bottom we have a proportionate amount to add to friction. It may be asked, What about the allowance for machinery resistances and passing round curves? I cover all this by simply adding one-half to the power which would otherwise be required. The American continent is ahead of Europe in the matter of hauling engines. I sent out to the Intercolonial Coal Mining Company, of Montreal and Nova Scotia, some years ago, a pair of powerful compound hauling engines which are now working, and working well, with an initial steam pressure of 150 lbs. per square inch, and expanding, if I remember rightly, nine times.

The various systems of haulage are:

Self-acting gradients, in which the roadways have a sufficient downward inclination out to need no power.

Direct haulage, in which the downward inclination is in, and sufficient for empty tubs to run in without power.

Tail-rope haulage, where we have an irregular gradient and require one rope to pull empty tubs in and another rope to pull loaded tubs out.

The endless system of haulage, in which we have a continuous rope or chain upon a double line of road, and loaded tubs are always coming out on one road and empty tubs are always going in on the other road.

Probably one example will show with sufficient clearness the manner in which we work out the resistances with which an endless rope system of haulage has to deal. The system is one mile in length; the rope, which travels one mile per hour, weighs 4 lbs. per yard, and delivers 50 tons of coal per hour, in tubs which weigh each, when empty, 3 cwt., and carry each 10 cwt. The average gradient falls from the pit bottom 1 in 10. We want to know:

1. The total resistance upon the system.
2. The size of cylinder to overcome such resistance, average effective pressure of steam 40 lbs. per square inch, and piston speed 250 ft. per minute.
3. The actual horse power.

The system being one mile long, and quantity delivered being 50 tons an hour, we shall have 50 tons of coal upon the rope at one time, which means 100 loaded and 100 empty tubs. Coal weighs $50 \times 2{,}240 = 112{,}000$ lbs.; tubs weigh $200 \times 3 \times 112 = 67{,}200$ lbs.; rope weighs $3.520 \times 4 = 14{,}080$ lbs.; making a total of 193,280 lbs. Then, $193{,}280 \div 28 = 6.900$ lbs. of friction. The descending tubs and rope will balance ascending tubs and rope. We have 50 tons $\times\ 2{,}240 = 112{,}000$ lbs. of coal rising 1 in 10; and $112{,}000 \div 10 = 11{,}200$ lbs., which added to 6,900 lbs. gives a total of 18,100 lbs., to which add one-half, or 9,050 lbs. for resistances of engine, machinery, etc., and we have 27,150 lbs. as total resistance of haulage. The rope travels one mile $= 5{,}280$ ft. per hour $\div\ 60 = 88$ ft. per minute. The piston travels 250 ft. per minute. Therefore $27.150 \times 88 = 2{,}389{,}200 \div 250 = 9{,}556{\cdot}8$ lbs. pressure required upon the piston, and $9{,}556{\cdot}8 \div 40$ lbs. steam pressure $= 239$ square inches very nearly; and the square root of $(239 \div {\cdot}7854) =$ about 17½ in. diameter of cylinder. Now, lastly, for the actual horse power. $239 \times 40 = 9{,}556{\cdot}8 \times 250 = 2{,}389{,}200 \div 33{,}000 = 72{\cdot}4$ horse power. If we make our engine 3 ft. stroke = 41⅔ revolutions per minute, and if we make the driving pulley 4 ft. diameter = 7 revolutions per minute, the gearing will be 6 to 1. It must not be supposed that I am condemning all systems of haulage except the endless rope. I am well aware, from personal observation, of the excellent arrangement of tail rope, but, after due consideration and allowance, I prefer the endless rope.

WINDING MACHINERY.

Now we pass out of the mine; and, coming back to the surface, we deal with winding machinery. For winding engines I prefer a pair of horizontal direct-acting engines, either one separately capable of raising the load. The stroke should be twice the diameter of the cylinder; up to 30 in. diameter probably slide valves will answer well enough; beyond that, I prefer Cornish valves. In my opinion back piston rods are neither desirable nor useful. The most efficient brake is, as I think, the "Burns" brake, applied underneath, and allowing a leverage of 200 to 1. The diameter of winding drum depends very much on the size of the engines, and may be anything between 10 ft. and 30 ft. The parallel drum answers well enough, provided we have a balance rope, otherwise it may mean engines double the size that would otherwise suffice.

It is not difficult to understand that with an ordinary parallel drum we cannot have a uniform load because the ascending load is always diminishing by reason of the ascending rope coiling on the drum, and the descending load is always increasing by reason of the descending rope coiling off the drum. This we remedy by attaching a tail-rope under the cages, the rope hanging in the pit and one end attached to each cage. Or we may have a properly proportioned spiral drum. The Koepe system of winding dispenses with winding drums and substitutes a pulley, with one winding rope and an end holding each cage and a tail-rope under the cages. I consider the Koepe arrangement an excellent one, and enables smaller engines to do the work. The winding rope always runs in one line and upon one circumference, and the load is uniform throughout the winding.

The proper distance from headgear pulley to drum depends largely upon size of drum and depth of pit. I have found that with 400 yards pit and 15 ft. drum, 90 ft. gives good results. There is an interesting problem which may be worked arithmetically to determine a winding drum which shall put a uniform statical load upon the engine. Call loaded cage at bottom A, empty cage at top B, loaded cage at top C, empty cage at bottom D; to have a unform load A — B must equal C — D.

Let us take an example:

Loaded cage at bottom = 2 tons rope, 2 tons cage, 3 tons tubs and coal = 7 tons.

Empty cage at top = 2 tons cage, 1 ton tubs = 3 tons.

Loaded cage at top = 2 tons cage, 3 tons tubs and coal = 5 tons.

Empty cage at bottom, 2 tons rope, 2 tons cage, 1 ton tubs = 5 tons.

Call large diameter of drum 30 ft. and call small diameter x; find x:

$$A - B = C - D.$$
$$7 \times x - 3 \times 30 = 5 \times 30 - 5 \times x.$$
$$7x - 90 = 150 - 5x.$$
$$12x = 240.$$
$$x = 20 \text{ ft.}$$

Now substitute 20 for x, and see how it works out.

$$7 \times 20 - 3 \times 30 = 5 = 30 - 5 \times 20.$$
$$140 - 90 = 150 - 100.$$
$$50 = 50.$$

Maximum diameter, 30; minimum diameter, 20.

I have said nothing as to vertical drums for flat winding ropes, simply because in my opinion there should be no flat winding ropes. We have shown that the uniform net moment of load in foot-tons upon our winding engines in this particular example is 50 in terms of diameter, or 25 in terms of radius or × 3·1416 = 78·64 in terms of semi-circumference, and × 2,240 = 176,153·6 in foot-pounds. Now, what size should our engines be that an engine of a pair should be equal to that load? Suppose we have our average effective steam pressure of 60 lbs. per square inch on the piston, then 176,153·6 ÷ 60 = 2,936, which represents in theory the area of piston in square inches × length of stroke in feet. But in practice we must add one-half for general resistances, and 2,936 + 1,468 — 4,404. I am not quite able to put in a sufficiently simple arithmetical rule to determine the respective proportions in this 4,404 of piston area and length of stroke; but we may assume any length of stroke we please, always aiming to make stroke equal twice diameter of cylinder. In this case we will assume 5½ ft. stroke and 4,404 ÷ 5½ = 801 square inches area, and square root (801 ÷ ·7854) = very nearly 32 in. diameter of cylinder. We may, therefore, now lay down the following rule that the net load in foot-tons on the drum in terms of radius × 3·1416 × 2,240 will equal average effective pressure in pounds per square inch on the piston × area of piston in square inches, with one-half added for frictional resistances × length of piston stroke in feet. A good pair of winding engines should be capable of making an average piston speed of 400 ft. per

minute; the steam pipes supplying the engines should have an area one-tenth the area of both cylinders combined, and the exhaust pipes slightly larger. Since I wrote upon winding appliances several years ago, practically no development has been made with the Kœpe system. Nor has anything much been done in applying condensers to winding engines. With cheap fuel it matters not so much, but better times and higher prices are coming in the coal trade, and the fuel which could be saved by applying condensers to winding engines will be worth serious consideration.

I have received a good deal of criticism as having allowed too much power in winding engines. Well, I still hold that we should always have a pair of engines, and each one engine of the pair should be equal to the work. To get up speed in a few seconds we want more power than would be represented by the load to be lifted. I offer here a simple practical rule. In a properly balanced winding arrangement, with uniform load, multiply the weight of coal in pounds by the average speed of the cage in feet per minute; add one-half to cover the frictional resistances, and call that the load. Then the power which must equal this must be the average effective pressure of steam in pounds per square inch upon the piston, multiplied by the area of one cylinder in square inches, and multiplied again by the average speed of the piston in feet per minute.

Approximately the average effective pressure of steam will be two-thirds of the pressure shown upon the gauge near the engines.

Another equally simple and equally practical rule would be to take in the one case not the average speed of the cage, but the average circumference of the drum in feet; and in the other case not the average speed of the piston, but twice the length of the stroke in feet.

What we call an efficient brake is one which will hold without fear of running away with the cage and load in any position.

To find the actual horse power of an engine for hoisting any load out of a shaft at a given rate of speed.—To the weight of the loaded wagon add the weight of the rope and cage. This will give the gross weight.

Then $\text{H. P.} = \dfrac{\text{gross weight in lbs.}}{33{,}000} \times$ speed in feet per minute, and add from 25 to 50% for contingencies, friction, etc.

Example.—Having a shaft 600 ft. deep, gross weight of load 20,000 lbs., to be hoisted in 1½ minutes, what horse power is required?

$\text{H. P.} = \dfrac{20{,}000}{33{,}000} \times 400$ (or speed in feet per minute) = 243 H. P., nearly. To which add 35% for contingencies, and we have 328 H. P.

In a shaft with two hoistways use the net weight + the weight of one rope, instead of the gross weight.

The following rules regarding winding engines will be found of great practical value:

(1.) To find the load which a given pair of engines will start.—Multiply the area of one cylinder by the average pressure of the steam per square inch in the cylinder, and twice the length of the stroke. Divide this by the circumference of the drum, and deduct ⅓ for friction, etc.

Example.—Having a pair of engines, cylinders 20 in. diam. by 40 in. stroke, the drum 12 ft. diam., and the pressure at steam gauge 50 lbs., steam cut-off at ¾. Find from the foregoing table the average pressure of steam in cylinder, which is 48·2 lbs.

Then area of cylinder = 314·16 sq. in. 314·16 × 48·2 × 80 = 1,211,400·96.

The circumference of the drum = 452·4 in. 1,211,400·96 ÷ 452·4 = 2677 − ⅓ of 2677 = 1784 lbs., or the net load.

The gross load would include the weight of rope, cage and car, but as these are balanced by the descending rope, cage and car, the net load only is found. The drum mentioned is cylindrical. These remarks also apply to rule 2.

(2.) Knowing the load and the diameter of drum, and the length of stroke, the cut-off and pressure of steam at steam gauge to find the area and diameter of cylinders.—Multiply the load by the circumference of the drum, and add one-half for friction, etc. Divide this by the mean average steam pressure, multiplied by twice the length of the stroke.

Example.—Having the drum 10 ft. in diameter, the stroke 6 ft., the steam pressure at gauge 60 lbs., the cut-off at ¾ of stroke, and the load 5 tons or 11,200 lbs.

Then 11,200 × 31·416 (circumference of drum) = 351,859. 351,859 + ½ or 175,930 = 527,789.

The mean average pressure = 57·8 lbs., 57·8 × (6 × 2) = 693·6. 527,789 ÷ 693·6 = 761, square inches, area of piston.

761 ÷ ·7854 = 969. $\sqrt{969}$ = 31·13 in., or diameter of cylinder.

(3.) To find the approximate period of winding with a pair of direct acting engines.—Assume the piston to travel at an average velocity of 400 ft. per minute, and divide this by twice the length of the stroke, and multiply by the circumference of the drum. This gives the speed of cage in feet per minute. Divide depth of shaft by this, and the result will be the period of winding.

EXAMPLE.—Drum 31·416 ft. circumference, stroke 6 ft., depth of shaft 500 yds. = 1,500 ft. Then

400 ÷ 12 = 33·33. 33·33 × 31·416 = 1,047·1. 1,500 ÷ 1,047·1 = 1·43 min., or about 1 min. 26 sec.

(4.) To find the useful horse power during a winding.—Multiply the depth of shaft by net weight raised; divide this by number of minutes occupied in winding, and divide again by 33,000.

EXAMPLE.—Net weight 2 tons = 4,480 lbs., depth 1,500 ft., period of winding 1·43 minutes.

Then 4,480 × 1,500 = 6,720,000.
6,720,000 ÷ 1·43 = 4,699,301.
4,699,301 ÷ 33,000 = 142 + H. P.

To find the horse power of an engine required to hoist a given load up a single track incline in a given time.—Multiply the length of the incline in feet by the natural sine of the angle of inclination, which will give you the vertical lift. Divide the vertical lift by the given time in minutes. Multiply this by the gross load, including weight of rope, and divide the product by 33,000.

EXAMPLE.—Length of incline, 600 ft.; angle of inclination, 35°; weight of loaded car and 600 ft. of rope, 5,000 lbs.; time of hoisting, 2 minutes. Required, the horse power.

Sine of 35° = ·573576.
·573576 × 600 = 344·1456.
344·1456 ÷ 2 = 172·728.

$$\frac{172{\cdot}728 \times 5000}{33{,}000} = 26 + \text{H. P.}$$

Add from 25% to 50% for contingencies, friction, etc. In colliery practice 50% is not any too much to add, because the condition of track, cars, etc., is not as good, as a general rule, as on railroad planes.

To find the horse power of an engine required to hoist a given load up a double track incline in a given time.—Proceed as above, using the net load, to which should be added the weight of one rope, instead of the gross load.

HEADGEAR PULLEYS.

Headgear pulleys should, properly, be as large as mean diameter of winding drum, and failing that, as large as convenient and practicable. They should be turned on the part where the rope runs and have metal to allow for wear at the bottom of the groove. Headgear pulleys should be fixed to run quite true in the direction of their circles and should have no side movement. The bearings should be quite smooth, quite round, long and as small in diameter as is consistent with safety. All this is with a view to reduce friction.

ROPES

I propose to say little about. Flat ropes are an abomination; they are full of vices and have hardly any virtues. Compared with round ropes they approximately cost twice as much at first, weigh twice as heavy and wear half as long. I prefer round ropes to be of the best possible material, so as to get the maximum of strength with the minimum of weight. Each winding rope should have the wires of which it is made tested to breaking strain and a record kept, a piece of the rope when made tested to breaking strain and a record kept. The working load, including everything (cage, tubs, coal and rope itself), should never be allowed to exceed one-tenth of this latter amount. I have tried once or twice to lay down rules for determining strength of ropes, but really I know of no very reliable one, because the wire varies, and even ropes from similar wire will vary. To allow a margin of safety 10 may seem high, and is high, but it is not the steady load in winding we have to allow for, but the enormous strain at the commencement of the winding, which may and does amount to several times the load.

Securing the winding rope within the drum is easy, on account of the tremendous resistance afforded by coil friction, but there must be no sharp bends in

passing through the drum rim. The usual method of capping is by hoops and rivets. These latter are almost certainly an injury, and with the wires of the rope well turned back and neatly lapped, forming a not excessively tapered end, with a well fitting capping and well fitting and very slightly tapered hoops, no rivets at all are needed.

I find from the rope card of an eminent rope manufacturer that in the higher qualities of plough steel we arrive at breaking strains and safe working loads about as follow; margin of safety, 10:—

Diameter of rope. Inch.	Breaking strain. Tons.	Working load. Cwt.	Diameter of rope. Inch.	Breaking strain. Tons.	Working load. Cwt.
½	10½	21	1⅛	51	102
⅝	16½	33	1¼	66	132
¾	24	48	1⅜	72	144
⅞	31½	63	1½	90	180
1	40½	81			

I give these figures, having reason to consider them fairly reliable, and will not attempt here to lay down any rule.

CONDUCTORS.

In the matter of conductors, I have a dislike for rigid guides in pit shafts. There may be cases where shafts are so full of pipes and landings and horse-trees that only rigid conductors can be applied; in such cases apply them, but in no other. We cannot have a rigid conductor absolutely perpendicular; the inevitable settlement makes this quite impossible. I prefer the wire conductor because of its flexibility, allowing free and unimpeded winding. It is easily put in, requiring only attachment in the headgear, and weighting and steadying at the bottom. They allow contraction and expansion; rigid conductors will not. A reasonable weight for each conductor to be attached at the bottom is about 1 ton for each 200 yards in depth. The number of conductors to each cage will be two or three or four, according to magnitude of load and depth of pit. When two cages work in the same shaft 6 in. between cages back to back is ample, and in addition to conductors connected with each cage, there should be two conductors between the cages and not attached to them. The all-important point in connection with conductors is that the pit shaft and every conductor in it should be absolutely vertical.

SAFETY CAGES.

A good many years ago what are known as safety cages were not uncommon in England, and on the Continent of Europe they were compulsory by law. Their action is simple; so long as the load is on the rope the catches on the cage are out of action; but when a rope breaks, and the load goes off, the catches come into action, grip the conductors, and hold the cage. There were two advantages which these safety cages formerly had—the speed of winding was slow, and the conductors were of wood, affording facilities for gripping. Now the speed of winding is very rapid, and the conductors, a good many of them, are of wire. There is some danger of such cages acting when they should not, and not gripping when they should. It is a fact that safety cages are not now as numerous in proportion to the collieries as formerly, and on the Continent are not now compulsory. Safety cages are intended to act when ropes break; but those who do not care for them say that ropes of proper material, well made, worked on proper machinery, and not overloaded, ought not to break, and will not break. It must be remembered also that even with a safety cage we have nothing to prevent the lower part of a broken rope falling down the pit and doing injury. Mr. Edward Omerod, of Atherton, near Manchester, England, quite recently exhibited to me a safety cage of ingenious construction and equal in action to anything of the kind I have seen.

DETACHING HOOKS.

An accident which occurred in the neighborhood of St. Helens, Lancashire, England, some ten or twelve years ago, in which a cage was overwound, and eight or ten men were killed, gave a great impetus to the application of what we call detaching hooks, which, when a cage is drawn too far, detach the rope and hold the cage in the headgear. Previously there had been a prejudice against them; people said that the best preventive against overwinding was a careful engineman, and that detaching hooks would provoke overwinding. This was not a correct way of putting it; because detaching hooks will tell us of overwinding of which without we might be ignorant, and a rope might have

received serious injury. There is no more careful and reliable class of workmen than the colliery engineman who on an average has probably 60,000 windings a year, and who certainly does not make one overwind in each year. But enginemen are only human, and a slight dislocation of the machinery may make an occasional overwind inevitable. Detaching hooks ought to be universally applied. Several accidents in which the rope has been detached all right, but the hook has smashed, and has allowed the cage to rush down the pit, would seem to show that in addition to the detaching hook itself we ought to have catches in the headgear as an additional safeguard.

APPLIANCES TO PREVENT OVERWINDING.

It ought not to be forgotten that detaching hooks do not prevent overwinding; they only prevent a cage being drawn over the headgear, and are intended to support the cage in the headgear; and they have no influence whatever upon a descending cage, which may go rushing on to havoc and destruction. This has led to the introduction of special appliances for the prevention of overwinding. In the event of an engineman losing control of his engine, and it runs away at a high speed, these appliances shut off the steam and apply the brakes, and stop the engine. Also, if the cage starts the wrong way, or is drawn too far above the pit bank, the same operation results. There is a natural disinclination to clothe an engine and surround an engineman with too many appliances, calculated to prevent this and prevent that; but we do think that a well-designed and effective appliance which will without hampering regular work, make overwinding impossible, is a useful and necessary adjunct to winding engines. Mr. Alexander Bertram has recently patented and applied at the Alexandra Collieries of the Wigan Coal and Iron Company, Wigan, Lancashire, England, an excellent and successful appliance known as the "Visor," which has satisfied all practical tests.

VENTILATING MACHINERY.

There is another very interesting section of our subject—namely, that of machinery for ventilation. We do not propose to explain, or to try and explain how collieries are ventilated, but shall simply say sufficient to explain generally what is meant by appliances for ventilation, and some of our own views regarding them. The ordinary furnace method is simply to place a large fire at the bottom of one of the pit shafts, called the upcast. This fire heats the air in this shaft, and in consequence the air expands, and by expansion becoming lighter, rises, and other and colder air coming in to take its place, and being heated and becoming lighter in its turn, constantly rises, and so a current all through the mine is set up and kept up.

The objections to furnace ventilation are—the danger of causing fire in the surroundings of the furnace, the nuisance and even injury to the shaft, and the nuisance and damage caused by the discharging gases at the surface. For very deep shafts no more effective mode of ventilation can be applied than that by furnace.

Mechanical ventilation, as now very largely adopted, places a fan at the top of the upcast, and, by constantly drawing air out, produces a current in this way. The action of the fan is very simple, and based upon a very interesting principle. There is a natural law, well known as the first law of motion, to the effect that bodies at rest will remain at rest, and will have no tendency to motion unless acted upon by some external force; and that bodies in motion will remain in motion, and move in straight lines with unvarying velocity, unless acted upon by some external force.

Now we can see at once that if we set a fan in motion, if the air within it simply remained within it, we should go on churning the air and producing no current, therefore doing no useful work. But immediately we put the fan in motion, the air within it, following the natural law, moves off, not in circles, but in straight lines, to the circumference, leaving a vacuum behind, into which the other air rushes, and so a current is produced and maintained.

In connection with this first law of motion there is no difficulty in showing and proving the first portion, which applies to bodies at rest, and remaining at rest; but it is not so easy to show and prove the second portion—namely, that bodies in motion will remain in motion.

We cannot show it absolutely, because we cannot entirely remove all external forces, but we can show that relatively as we lessen the influence of external forces, the law is relatively correct. A stone thrown in a quiet atmosphere will travel further and longer than a stone thrown against a strong wind. A stone thrown along a muddy road will not travel so far as when thrown along a comparatively smooth pavement, and when thrown upon a pond or lake covered with ice will travel much further.

A wheel resting upon rough bearings will, when the turning power is removed, come to rest much more quickly than when rotating upon very smooth surfaces, and still longer when supported upon what we term friction rollers. That moving bodies endeavor to travel in straight lines, and resist diversion from those straight lines, is very generally understood. Steam and water in pipes and passing round curves lose power; conveyances capsize in turning corners quickly; and a very excellent practical illustration is on railways, where on curves we elevate the outer rails to counteract the endeavor of the train to pass on in a straight line and leave the rails. The amount of elevation given to the outer rail depends upon the highness of the speed and the sharpness of the curve.

Mechanical ventilators at one time worked like pumps with gigantic pistons, but the reversal of the straight line actions, and the opening and closing of large valves necessitated so slow a movement, and produced so much wear and tear, that the machine was found to be cumbersome and inefficient. A fan moves continually in one direction, has no reversals of movement, no valves or clacks to open and close, and practically no parts to suffer wear and tear.

It is sometimes asked why ventilating fans are always exhausters, and not sometimes used to force the air into the mine.

Well, they are in some cases used to force air in, and there is probably no good reason one way or the other. From time immemorial ventilation of mines has been worked upon the principle of exhaustion, and the exhausting fan simply follows on the same lines.

It will be readily understood that when fans were first proposed as colliery ventilators there was a good deal of prejudice to be overcome, and a good deal of unbelief to remove. People said that they would get out of order, and that all the lives in a mine would be endangered by stoppage in the ventilation arising out of break down in the fan machinery. As a matter of fact ventilating fans do not break down; there is really nothing to break down, and even if they were so liable we could provide not only duplicate fan engines, as all well appointed concerns already do provide, but we could also have, as in one or two present cases, duplicate fans. We saw a few months ago at Newport Abercarne, South Wales, an excellent ventilating plant of two fans and two engines.

The very eminent engineers like the late Nicholas Wood and the late Sir William Fairbairn said thirty years ago that these ventilating machines might do fairly well for shallow pits and for small currents, but would be inapplicable to deep mines and quantities of air such as 250,000 cubic feet per minute. Improvements and changes always do meet with opposition, and have to pass through the furnace of practical experience. The steam engine, the locomotive engine, the railway system, steam navigation, every mechanical and industrial invention, everything that has made our mining, and iron, and steel, and engineering industries great, have all had to meet and battle with and conquer predjudice and opposition. Mechanical ventilation has met difficulties, and has successfully overcome them; and now we have thousands of fans, ventilating mines of all depths, and pass out quantities of air from a few thousands to half a million cubic feet per minute, for hours and days and weeks and months successively. There is something very striking to stand in an air drift and feel the current of nearly 1,000 tons of air per hour drawn through miles of underground passages, and all effected by a simple revolving wheel. There is a Guibal fan at the Bickershaw Collieries of Messrs. Ackers, Whitley & Co., Leigh, Lancashire, England, producing 500,000 cubic feet of air per minute.

We shall only mention a few of the numerous types of fans. That of Nasmyth has straight radial parallel blades, drawing air in at the centre, as indeed they all do, and expelling it all round the circumference. That of Waddle, with nicely curved and tapered passages so proportioned that the area of the cross section multiplied by the circumference is a constant quantity, and discharging the air freely all round. That of Guibal, which has parallel blades, curved forwards at the tips. The air can only get away at one point and enters into an enlarging chimney. That of Schiele which has blades, curved backwards at the tips, and tapered so as to promote uniform area. There is a spiral casing all round leading into an enlarging chimney.

We shall probably not be considered too presumptuous if we remark that none of these fans are exactly of that form which we think correct, and it will be well to explain what we believe to be the correct principles of fan construction. (1.) The width of the blades or passages should so diminish to the circumference that the circumference at any point multiplied by the width at that point will be a constant quantity. This has been recognized and carried out in the Waddle and Schiele Fans. (2.) The outline of the blades from inlet to outlet should be of special form. Mere churning of the air in the fan is work wasted.

The more direct the air can pass through the fan the better. If we take a circular piece of wood representing the fan and fix it upon a centre, cause it to revolve, and then let the point of a pencil or chalk representing a particle of air passing through the fan trace a line on the revolving piece of wood, we shall describe not a straight line, but a curve running backwards into the circumference and entering into that circumference tangentially. This is no new theory of our own. Near upon forty years ago experiments were made upon centrifugal pumps which are upon similar lines to ventilating fans, except that they raise water, and the following remarkable results came out. Pumps with straight radial blades showed a useful effect of 22 per cent. Pumps with straight blades inclined backward at an angle of 45° showed a useful effect of 44 per cent. Pumps with blades curved backwards and running into the circumference tangentially showed a useful effect of 66 per cent. (3.) The outlet for the air should be made as easy as possible all round. Waddle affords a free discharge all round the circumference, but there is nothing to prevent the impulse of the discharging air against the motionless air outside. Guibal provides an enlarging chimney into which the air is delivered, the increasing area lessens the velocity, the liberated energy by reduced velocity carries out the air that is in the chimney, and the whole discharges into the atmosphere easily and with little shock. Schiele improves upon this, and virtually has an enlarging chimney carried all round the fan in the form of a spiral casing. It is only fair to say that the Waddle, Guibal, and Schiele, all do good work.

A fan has been introduced more recently than are the foregoing. It is the invention of an English clergyman named Capell, and bears his name. It approaches more nearly to the requirements which I have laid down than any of its competitors, and produces, as I can well believe it will produce, although I have had no experience with it, a high useful effect, namely, from 70 to 80 per cent., and is capable of a water gauge as high as 10 inches. The Patent Anti-Vibration Shutter added to the Guibal fan has made that fan almost absolutely non-vibratory, enables higher speeds and increases the efficiency. Experiments show 75 per cent. of useful effect.

What do we mean by the expression "useful effect of a fan?" We measure the horse power of a fan by taking the quantity of air passing through in cubic feet of air per minute × inches of water-gauge × 5·2, because each inch of water gauge represents a pressure or vacuum of 5·2 lb. per square foot and ÷ 33,000. Then the indicated or actual horse of the fan engine we get by taking the area of piston in square inches × average effective pressure in pounds per square inch on the piston as ascertained by the indicator × speed of the piston in feet per minute ÷ 33,000.

If the ventilating horse power is 60 and the engine horse power 100, we call the useful effect of fan 60 per cent. Now such a method of calculation is very clearly wrong. The useful effect of a fan is the percentage which the ventilation bears, not to the horse power generated by the fan engine, but to the horse power given off by the fan engine after deducting its own resistance, which may be 5, 10, 15 or 20 per cent. of its power.

I have not tried to lay down any rule as to sizes of fans to produce certain quantities, but give the following examples in actual practice :—

Type of Fan.	Circumferential velocity in feet per minute.	Water-gauge in inches.	Cubic feet of air per minute.
Guibal............	3,468	1·125	120,000
"	5,780	2·700	300,000
"	3,769	1·100	76,000
"	4,520	1·500	138,243
"	5,635	2·900	278,000
"	5,024	2·250	126,000
"	4,470	1·750	122,848
"	3,768	1·250	66,187
"	3,770	1·250	63,000
"	6,069	2·600	260,000
"	6,047	3·750	250,000
"	4,335	1·750	191,000
Waddle............	5,652	1·750	110,000
"	6,531	2·400	210,000
Schiele............	6,452	1·800	147,000
"	6,050	1·500	60,000
"	5,970	1·200	90,000
"	5,032	1·500	160,000
"	4,077	1·600	67,730

The following approximate estimates of fan capabilities may possibly be found useful:

A. **A small type of fan, open, running; that is, open all round the circumference for water gauges up to 2 inches; beyond that a spiral casing and a Guibal chimney.**

6 ft. diameter,	**30,000**	**cubic feet**	**of air**	**per minute.**
7½ "	**50,000**	**"**	**"**	**"**
10 "	**75,000**	**"**	**"**	**"**
12 "	**100,000**	**"**	**"**	**"**
16 "	**150,000**	**"**	**"**	**"**
18 to 20 "	**200,000**	**"**	**"**	**"**

B. **A small type of fan, quick running, blades curved backwards, spiral casing, Guibal chimney, and *single* inlet.**

Diameter in feet,	Width in feet.	Rev. per min.	Water Gauge in inches.	Quan. of air cub.ft.pr. min.
8·0	4·0	300	2½	50,000
10·0	4·6	240	2½	75,000
12·0	5·4	210	2½	100,000
12·6	5·8	210	2½	125,000
15·0	6·6	180	2½	150,000

C. Same class of fan, but *double* inlet.

Diameter in feet.	Width in feet.	Rev. per min.	Water Gauge in inches.	Quan. of air cub.ft.pr. min.
8·0	4·0	300	2½	100,000
10·0	4·6	240	2½	150,000
12·0	5·4	210	2½	200,000
12·6	5·8	210	2½	250,000
15·0	6·6	180	2½	300,000

D. Guibal fan, ordinary construction.

Diameter in feet.	Width in feet.	Quan. of air cub. ft. per min.
10	3 to 4½	20,000
12	4–5	35,000
16	6–7	55,000
18	7–8	65,000
20	7½–8½	75,000
24	8–9	85,000
30	10–11	110,000
35	12–13	150,000
40	12–14	200,000
46	12–15	250,000
50	12-15	300,000

The volume of air exhausted by a fan will depend very much on the condition and dimensions of the airways in the mine. Fans of similar dimensions do not always produce similar results.

What do we mean by the term water-gauge? and what do we mean by 5.2?

If we blow air into a furnace, we increase the pressure, and the increased pressure can be measured by water-column or water-gauge, each inch of water-gauge representing a pressure of 5.2 lbs. per square foot.

If we exhaust air from a mine, we reduce the pressure, and the reduced pressure is measured by water-column or water-gauge, each inch of water-gauge representing a reduction of pressure amounting to 5.2 lbs. per square foot.

Reliable fan makers have an abundant experience to go upon as to sizes and speeds, and all ventilating fans should be capable of much more than the ordinary amount of work, so as to be ready for an emergency.

We have now upon the American Continent and in England and on the Continent of Europe many thousands of ventilating fans at work, and there is no difficulty in getting information as to what many of them are doing. A colliery manager about to put down a fan would do well to ascertain from a number of collieries where fans are in use, the diameter and width, the number of revolutions per minute, the quantity of air in cubic feet per minute, the water-gauge in inches. Upon such information he can readily determine his own proportions.

CONCLUSION.

Now, a word or two of advice generally. In deciding upon colliery machinery, there should always be power, and ample power; by ample power is meant more than is likely to be needed. Engines a little larger than absolutely essential cost little more at first and nothing extra afterwards; whereas engines not large enough and machinery not strong enough, are a constant harass in the working of a colliery. Further, all colliery machinery and appliances should be of the best materials and workmanship.

For further information upon colliery machinery may I refer my numerous friends in America to my work on "The Mechanical Engineering of Collieries."

WIGAN, England, 1890. C. M. PERCY.

STEAM-RAISING.

FUELS, INCRUSTATION AND SCALE, BOILER AND PIPE COVERING, AND RULES FOR CARE OF BOILERS.

(Abridged from "Steam," published by Babcock & Wilcox Co.)

FUELS.

The value of any fuel is measured by the number of heat units which its combustion will generate, a unit of heat being the amount required to heat one pound of water one degree Fahrenheit. The fuel used in generating steam is composed of carbon and hydrogen, and ash, with sometimes small quantities of other substances not materially affecting its value.

"Combustible" is that portion which will burn; the ash or residue varying from 2 to 36 per cent. in different fuels.

TABLE OF COMBUSTIBLES.

Kind of Combustible.	Air Required.	Temperature of Combustion.				Theoretical Value.		Highest Attainable Value under Boiler.	
	In Pounds per pound of Combustible.	With Theoretical Supply of Air.	With 1½ times the Theoretical Supply of Air.	With twice the Theoretical Supply of Air.	With three times the Theoretical Supply of Air	In Pounds of Water raised 1° per pound of Combustible.	In lbs. of Water evaporated from and at 212°, with 1 lb. Combustible.	With Chimney Draft.	With Blast, Theoretical Supply of Air at 60°, Gas 320°.
Hydrogen	36·00	5750	3860	2860	1940	62032	64·20		
Petroleum	15·43	5050	3515	2710	1850	21000	21·74	18·55	19·90
Carbon { Charcoal, Coke, Anthracite Coal. }	12·13	4580	3215	2440	1650	14500	15·00	13·30	14·14
Coal—Cumberland	12·06	4900	3360	2550	1730	15370	15·90	14·28	15·06
" Coking Bituminous	11·73	5140	3520	2680	1810	15837	16·00	14·45	15·19
" Cannel	11·80	4850	3330	2540	1720	15080	15·60	14·01	14·76
" Lignite	9·30	4600	3210	2490	1670	11745	12·15	10·78	11·46
Peat—Kiln dried	7·68	4470	3140	2420	1660	9660	10·00	8·92	9·42
" Air dried 25% water	5·76	4000	2820	2240	1550	7000	7·25	6·41	6·78
Wood—Kiln dried	6·00	4080	2910	2260	1530	7245	7·50	6·64	7·02
" Air dried 20% water	4·80	3700	2607	2100	1490	5600	5·80	4·08	4·39

There is a large difference in coals from different localities, and even adjacent mines. The following table of American coals, is compiled from various sources:

AMERICAN COALS.

COAL. STATE. KIND OF COAL	Per cent. of Ash.	Theoretical Value. In Heat Units.	Theoretical Value. Pounds of water evap.	COAL. STATE. KIND OF COAL	Per cent. of Ash.	Theoretical Value. In Heat Units.	Theoretical Value. Pounds of water evap.
Penn. Anthracite ..	3·49	14,199	14·70	Ill. Bureau Co... ..	5·20	13,025	13·48
" " ...	6·13	13,535	14·01	" Mercer Co.	5·60	13,123	13·58
" " ...	2·90	14,221	14·72	" Montauk	5·50	12,659	13·10
" Cannel.......	15·02	13,143	13·60	Ind. Block..........	2·50	13,588	14·38
" Connellsville.	6·50	13,368	13·84	" Caking.........	5·66	14,146	14·64
" Semi-bit'nous	10·70	13,155	13·62	" Cannel..	6·00	13,097	13·56
" Stone's Gas..	5·00	14,021	14·51	Md. Cumberland...	13·88	12,226	12·65
" Youghioghe'y	5·60	14,265	14·76	Ark. Lignite........	5·00	9,215	9·54
" Brown........	9·50	12,324	12·75	Col. "	9·25	13,562	14·04
Kentucky Caking ..	2·75	14,391	14·89	" "	4·50	13,866	14·35
" Cannel...	2·00	15,198	16·76	Texas "	4·50	12,962	13·41
" " ...	14·80	13,360	13·84	Wash. Lignite......	3·40	11,551	11·96
" Lignite ..	7·00	9,326	9·65	Penn. Petroleum....		20,746	21·47

The effective value of all kinds of wood *per pound*, when dry, is substantially the same. This is usually estimated at 0·4 the value of the same weight of coal. The following are the weights and comparative value of different woods by the cord:

Kind of Wood.	Weight.	Kind of Wood.	Weight.
Hickory, Shell bark.	4469	Beech....................	3126
" Red heart	3705	Hard Maple...............	2878
White Oak...............	3821	Southern Pine............	3375
Red Oak..................	3254	Virginia "	2680
Spruce...................	2325	Yellow "	1904
New Jersey Pine.........	2137	White "	1868

The first table gives, for the more common combustibles, the air required for complete combustion, the temperature with different proportions of air, the theoretical value, and the highest attainable value under a steam boiler, assuming that the gases pass off at 320°, the temperature of steam at 75 lbs. pressure, and the incoming draft to be at 60°; also that with chimney draft twice and with blast only the theoretical amount of air is required for combustion.

"Slack" or the screenings from coal, when properly mixed—anthracite and bituminous,—and burned by means of a blower on a grate adapted to it, is nearly equal in value of combustible to coal, but its percentage of refuse is greater.

Much is said nowadays about the wonderful saving which is to be expected from the use of *petroleum for fuel*. This is all a myth, and a moment's attention to facts is sufficient to convince any one that no such possibility exists. Petroleum has a heating capacity, when fully burned, equal to from 21,000 to 22,000 B. T. U. per pound, or say 50 per cent. more than coal. But owing to the ability to burn it with less losses, it has been found through extended experiments by the pipe lines that under the same boilers, and doing the same work, a pound of petroleum is equal to 1·8 pounds of coal. The experiments on locomotives in Russia have shown practically the same value, or 1·77. Now, a gallon of petroleum weighs 6·7 lbs. (though the standard buying and selling weight is 6·5 lbs.), and therefore an actual gallon of petroleum is equivalent under a boiler to twelve pounds of coal, and 190 standard gallons are equal to a gross ton of coal. It is very easy with these data to determine the relative cost. At the wells, if the oil is worth say two cents a gallon, the cost is equivalent to $3.80 per ton for coal at the same place, while at say three cents per gallon, the lowest price at which it can be delivered in the vicinity of New York, it costs the same as coal at $5.70 per ton. The Standard Oil Co. estimate that 173 gallons are equal to a gross ton of coal, allowing for incidental savings, as in grate bars, carting ashes, attendance, &c.

Sawdust can be utilized for fuel to good advantage by a special furnace and automatic feeding devices. Spent tan bark is also used, mixed with some coal, or it may be burned without the coal in a proper furnace. Its value is about one-fourth that of the same weight of wood, as it comes from the press, but when dried its value is about 85 per cent. of the same weight of wood in same state of dryness.

It has been estimated that on an average one pound of coal is equal, for steam-making purposes, to 2 lbs. dry peat, 2¼ to 2½ lbs. dry wood, 2½ to 3 lbs. dried tan-bark, 2¾ to 3 lbs. cotton stalks, 3¼ to 3¾ lbs. wheat or barley straw, and 6 to 8 lbs. wet tan-bark.

Natural gas varies in quality, but is usually worth 2 to 2½ times the same *weight* of coal, or about 30,000 cubic ft. are equal to a ton of coal.

INCRUSTATION AND SCALE.

Nearly all waters contain foreign substances in greater or less degree, and though this may be a small amount in each gallon, it becomes of importance where large quantities are evaporated. Far instance, a 100 H. P. boiler evaporates 30,000 lbs. water in ten hours, or 390 *tons* per month; in comparatively pure water there would be 88 lbs. of solid matter in that quantity, and in many kinds of spring water as much as 2,000 lbs.

The nature and hardness of the scale formed of this matter will depend upon the kind of substances held in solution and suspension. Analyses of a great variety of incrustations show that carbonate and sulphate of lime form the larger part of all ordinary scale, that from carbonate being soft and granual, and that from sulphate hard and crystalline. Organic substances in connection with carbonate of lime, will also make a hard and troublesome scale.

The presence of scale or sediment in a boiler results in loss of fuel, burning and cracking of the boiler, predisposes to explosion, and leads to extensive repairs. It is estimated that the presence of $\frac{1}{16}$ inch of scale causes a loss of 13 per cent. of fuel, ¼ in. 38 per cent. and ½ in. 60 per cent. The Railway Master Mechanics' Association of the U. S. estimates that the loss of fuel, extra repairs, etc., due to incrustation, amount to an average of $750 per annum for every locomotive in the Middle and Western States, and it must be nearly the same for the same power in stationary boilers.

The most common and important minerals in boiler scale are carbonate of lime, sulphate of lime, and carbonate of magnesia. Small amounts of alumina and silica are sometimes found, and an oxide of iron not infrequently is present as a coloring matter.

MEANS OF PREVENTION.

It is absolutely essential to the successful use of any boiler, except in pure water, that it be accessible for the removal of scale, for though a rapid circulation of water will delay the deposit, and certain chemicals will change its character, yet the most certain cure is periodical inspection and mechanical cleaning. This may, however, be rendered less frequently necessary, and the use of very bad water more practical by the employment of some preventives. The following are a fair sample of those in use, with their results:

M. Bidard's observations show that "anti-incrustators" containing organic matter help rather than hinder incrustations, and are therefore to be avoided.

Oak, hemlock, and other barks and woods, sumac, catechu, logwood, etc., are effective in waters containing carbonates of lime or magnesia, by reason of their tannic acid, but are injurious to the iron, and not to be recommended.

Molasses, cane juice, vinegar, fruits, distillery slops, etc., have been used with success so far as scale is concerned, by reason of the acetic acid which they contain, but this is even more injurious to the iron than tannic acid, while the organic matter forms a scale with sulphate of lime when it is present.

Milk of lime and metallic zinc have been used with success in waters charged with bicarbonate of lime, reducing the bicarbonate to the insoluble carbonate.

Barium chloride and milk of lime are said to be used with good effect at Krupp's Works, in Prussia, for waters impregnated with gypsum.

Soda ash and other alkalies are very useful in waters containing sulphate of lime, by converting it into a carbonate, and so forming a soft scale easily cleaned. But when used in excess they cause foaming, particularly where there is oil coming from the engine, with which they form soap. All soapy substances are objectionable for the same reason.

Petroleum has been much used of late years. It acts best in waters in which sulphate of lime predominates. As crude petroleum, however, sometimes helps in forming a very injurious crust, the refined only should be used.

Tannate of soda is a good preparation for general use, but in waters containing much sulphate, it should be supplemented by a portion of carbonate of soda or soda ash.

A decoction from the leaves of the eucalyptus is found to work well in some waters, in California.

For muddy water, particularly if it contain salts of lime, no preventive of incrustation will prevail except filtration, and in almost every instance the use of a filter, either alone or in connection with some means of precipitating the solid matter from solution, will be found very desirable.

In all cases where impure or hard waters are used, frequent "blowing" from the mud-drum is necessary to carry off the accumulated matter, which if allowed to remain would form scale.

When boilers are coated with a hard scale difficult to remove, it will be found that the addition of ¼ lb. caustic soda per horse power, and steaming for some hours, according to the thickness of the scale, just before cleaning, will greatly facilitate that operation, rendering the scale soft and loose. This should be done, if possible, when the boilers are not otherwise in use.

COVERING FOR BOILERS, STEAM PIPES, ETC.

The losses by radiation from unclothed pipes and vessels containing steam is considerable, and in the case of pipes leading to steam engines, is magnified by the action of the condensed water in the cylinder. It therefore is important that such pipes should be well protected. The following table gives the loss of heat from steam pipes naked and clothed with wool or hair felt, of different thickness, the steam pressure being assumed at 75 lbs. and the extreme air at 60°.

There is a wide difference in the value of different substances for protection from radiation, their value varying nearly in the reverse ratio of their conducting power for heat, up to their ability to transmit as much heat as the surface of the pipe will radiate, after which they become detrimental, rather than useful, as covering. This point is reached nearly at baked clay or brick.

TABLE OF LOSS OF HEAT FROM STEAM PIPES.

Thickness of Covering in in.	Outside Diameter of Pipe, without Felt.														
	2 in. diameter.			4 in. diameter.			6 in. diameter.			8 in. diameter.			12 in. diameter.		
	Loss in units per foot run per hour.	Ratio of Loss.	Feet in Length per H. P. lost.	Loss in units per foot run per hour.	Ratio of Loss.	Feet in Length per H. P. lost.	Loss in units per foot run per hour.	Ratio of Loss.	Feet in Length per H. P. lost.	Loss in units per foot run per hour.	Ratio of Loss.	Feet in Length per H. P. lost.	Loss in units per foot run per hour.	Ratio of Loss.	Feet in Length per H. P. lost.
0	219·0	1·00	132	390·8	1·00	75	624·1	1·000	46	729·8	1·000	40	1077·4	1·000	26
¼	100·7	·46	288	180·9	·46	160									
½	65·7	·30	441	117·2	·30	247	187·2	·300	154	219·6	·301	132	301·7	·280	92
1	43·8	·20	662	73·9	·18	392	111·0	·178	261	128·3	·176	225	185·3	·172	157
2	28·4	·13	1020	44·7	·11	648	66·2	·106	438	75·2	·103	385	98·0	·091	294
4	19·8	·09	1464	28·1	·07	1031	41·2	·066	703	46·0	·063	630	60·3	·056	486
6				23·4	·06	1238	33·7	·054	860	34·3	·047	845	45·2	·042	642

A smooth or polished surface is of itself a good protection, polished tin or Russia iron having a ratio, for radiation, of 53 to 100 for cast iron. Mere color makes but little difference.

TABLE OF CONDUCTING POWER OF VARIOUS SUBSTANCES.

(From Péclet.)

Substance.	Conduct'g Power.	Substance.	Conduct'g Power.
Blotting Paper	·274	Wood, across fibre	[illegible]
Eiderdown	·314	Cork	[illegible]
Cotton or Wool any density	·323	Coke, pulverized	[illegible]
		India Rubber	[illegible]
Hemp, Canvas	·418	Wood, with fibre	[illegible]
Mahogany Dust	·523	Plaster of Paris	3·86
Wood Ashes	·531	Baked Clay	4·83
Straw	·563	Glass	6·6
Charcoal Powder	·636	Stone	13·68

Hair or wool felt has the disadvantage of becoming soon charred from the heat of steam at high pressure, and sometimes of taking fire therefrom. This has led to a variety of "cements" for covering pipes—composed generally of clay mixed with different substances, as asbestos, paper fibre, charcoal, etc. A series of careful experiments, made at the Mass. Institute of Technology in 1871, showed the condensation of steam in a pipe covered by one of them, as compared with a naked pipe, and one clothed with hair felt, was 100 for the naked pipe, 67 for the "cement" covering, and 27 for the hair felt.

TABLE OF RELATIVE VALUE OF NON-CONDUCTORS.

(From Chas. E. Emery, Ph. D.)

Non-Conductor.	Value	Non-Conductor.	Value
Wood Felt	1·000	Loam, dry and open	·550
Mineral Wood No. 2	·832	Slacked Lime	·480
" with tar	·715	Gas House Carbon	·470
Sawdust	·680	Asbestos	·363
Mineral Wood No. 1	·676	Coal Ashes	·345
Charcoal	·632	Coke in lumps	·277
Pine Wood across fibre	·553	Air space undivided	·136

"Mineral wool," a fibrous material made from blast furnace slag, is a good protection, and is incombustible.

Cork chips, cemented together with water-glass, make one of the best coverings known.

A cheap jacketing for steam pipes, but a very efficient one, may be applied as follows: First, wrap the pipe in asbestos paper—though this may be dispensed with; then lay slips of wood lengthways, from 6 to 12 according to size of pipe—binding them in position with wire or cord; and around the framework thus constructed wrap roofing paper, fastening it by paste or twine. For flanged pipe, space may be left for access to the bolts, which space should be filled with felt. If exposed to weather, use tarred paper—or paint the exterior. A French plan is to cover the surface with a rough flour paste mixed with sawdust until it forms a moderately stiff dough. Apply with a trowel in layers of about ¼ inch thick—give 4 or 5 layers in all. If iron surfaces are well cleaned from grease, the adhesion is perfect. For copper, first apply a hot solution of clay in water. A coating of tar renders the composition impervious to the weather.

CARE OF BOILERS.

1. Safety Valves.—Great care should be exercised to see that these valves are ample in size and in working order. *Overloading* or *neglect* frequently lead to the most disastrous results. Safety valves should be tried at least once every day to see that they will act freely.

2. Pressure Gauge.—The steam gauge should stand at zero when the pressure is off, and it should show same pressure as the safety valve when that is blowing off. If not, then one is wrong, and the gauge should be tested by one known to be correct.

3. Water Level.—The first duty of an engineer before starting, or at the beginning of his watch, is to see that the water is at the proper height. Do not rely on glass gauges, floats or water alarms, but try the gauge cocks. If they do not agree with water gauge, learn the cause and correct it.

4. Gauge Cocks and Water Gauges must be kept clean. Water gauge should be blown out frequently, and the glasses and passages to gauge kept clean. The Manchester, Eng., Boiler Association attribute more accidents to inattention to water gauges, than to all other causes put together.

5. Feed Pump or Injector.—These should be kept in perfect order, and be of ample size. No make of pump can be expected to be continuously reliable without regular and careful attention. It is always safe to have two means of feeding a boiler. Check valves and self-acting feed valves should be frequently examined and cleaned. Satisfy yourself frequently that the valve is acting when the feed pump is at work.

6. Low Water.—In case of low water, immediately cover the fire with ashes (wet if possible) or any earth that may be at hand. If nothing else is handy, use fresh coal. Draw fire as soon as it can be done without increasing the heat.

Neither turn on the feed, start or stop engine, or lift safety valve until fires are out and the boiler cooled down.

7. *Blisters and Cracks.*—These are liable to occur in the best plate iron. When the first indication appears, there must be no delay in having it carefully examined and properly cared for.

8. *Fusible Plugs*, when used, must be examined when the boiler is cleaned, and carefully scraped clean on both the water and fire sides, or they are liable not to act.

9. *Firing.*—Fire evenly and regularly, a little at a time. Moderately thick fires are most economical, but thin firing must be used where the draught is poor. Take care to keep grates evenly covered, and allow no air-holes in the fire. Do not "clean" fires oftener than necessary. With bituminous coal, a "coking fire," *i. e.*, firing in front and shoving back when coked, gives best results, if properly managed.

10. *Cleaning.*—All heating surfaces must be kept clean outside and in, or there will be a serious waste of fuel. The frequency of cleaning will depend on the nature of fuel and water. As a rule, never allow over $\frac{1}{16}$ inch scale or soot to collect on surfaces between cleanings. Hand-holes should be frequently removed and surfaces examined, particularly in case of a new boiler, until proper intervals have been established by experience.

The *exterior* of tubes can be kept clean by the use of blowing pipe and hose through openings provided for that purpose. In using smoky fuel, it is best to occasionally brush the surfaces when steam is off.

11. *Hot Feed Water.*—Cold water should never be fed into any boiler when it can be avoided, but when necessary it should be caused to mix with the heated water before coming in contact with any portion of the boiler.

12. *Foaming.*—When foaming occurs in a boiler, checking the outflow of steam will usually stop it. If caused by dirty water, blowing down and pumping up will generally cure it. In cases of violent foaming, check the draft and fires.

13. *Air Leaks.*—Be sure that all openings for admission of air to boiler or flues, except through the fire, are carefully stopped. This is frequently an unsuspected cause of serious waste.

Blowing Off.—If feed-water is muddy or salt, blow off a portion frequently, according to condition of water. Empty the boiler every week or two, and fill up afresh. When surface blow-cocks are used, they should be often opened for a few minutes at a time. Make sure no water is escaping from the blow-off cock when it is supposed to be closed. Blow-off cocks and check-valves should be examined every time the boiler is cleaned.

15. *Leaks.*—When leaks are discovered, they should be repaired as soon as possible.

16. *Blowing Off.*—Never empty the boiler while the brick-work is hot.

17. *Filling Up.*—Never pump cold water into a hot boiler. Many times leaks, and in shell boilers, serious weaknesses, and sometimes explosions are the result of such an action.

18. *Dampness.*—Take care that no water comes in contact with the exterior of the boiler from any cause, as it tends to corrode and weaken the boiler. Beware of all dampness in seatings or coverings.

19. *Galvanic Action.*—Examine frequently parts in contact with copper or brass, where water is present, for signs of corrosion. If water is salt or acid, some metallic zinc placed in the boiler will usually prevent corrosion, but it will need attention and renewal from time to time.

20. *Rapid Firing.*—In boilers with thick plates or seams exposed to the fire, steam should be raised slowly, and rapid or intense firing avoided. With thin water tubes, however, and adequate water circulation, no damage can come from that cause.

21. *Standing Unused.*—If a boiler is not required for some time, empty and dry it thoroughly. If this is impracticable, fill it quite full of water, and put in a quantity of common washing soda. External parts exposed to dampness should receive a coating of linseed oil.

22. *General Cleanliness.*—All things about the boiler room should be kept clean and in good order. Negligence tends to waste and decay.

THICKNESS OF BOILER IRON REQUIRED AND PRESSURE ALLOWED BY THE LAWS OF THE UNITED STATES.

PRESSURE EQUIVALENT TO THE STANDARD FOR A BOILER 42 INCHES IN DIAMETER AND ¼ INCH THICK.

Thickness in 16ths.	DIAMETER. 34-in.	36-in.	38-in.	40-in.	42-in.	44-in	46-in.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
5	169·9	160·4	152·	144·4	137·5	131·2	125·5
4½	158·5	149·7	141·8	134·7	128·3	122·5	117·2
4	135·9	128·3	121·6	115·5	110	105·	100·
3¾	124·5	117·6	111·4	105·9	100·8	96·2	92·0
3½	113·2	106·9	101·3	96·2	91·7	87·5	83·0
3	101·9	96·2	91·2	82·6	82·5	78·7	75·1

GIFFARD'S INJECTOR.

Q = Quantity of water injected in gallons per hour.
P = Pressure of steam in atmospheres.
D = Diameter of throat in inches.

$$D = {\cdot}0158 \sqrt{\frac{Q}{\sqrt{P}}}$$

$$Q = \sqrt{P}\,(68{\cdot}4\,D)^2$$

Diameter of throat in decimals of an inch.	Delivery in gallons per hour with a pressure per square inch of 30	45	60	75	90
·1	56	69	80	89	98
·15	127	156	180	201	221
·2	226	278	321	360	393
·25	354	434	502	561	615
·3	505	624	722	807	884

PRESSURE OF STEAM AT DIFFERENT TEMPERATURES.

RESULTS OF EXPERIMENTS MADE BY THE FRANKLIN INSTITUTE.

Pressure in inches of mercury.	Temperature in degrees Fahr.	Pressure in inches of mercury.	Temperature in degrees Fahr.	Pressure in inches of mercury.	Temperature in degrees Fahr.
30	212°	135	298·5°	225	331°
45	235	150	304·5	240	336
60	250	165	310	255	340·5
75	264	180	315·5	270	345
90	275	195	321	285	349
105	284	210	326	300	352·5
120	291·5				

RULES FOR ENGINEERS.

If a gauge-glass breaks, turn off the water first and then the steam, to avoid scalding yourself.

Don't buy oil or waste simply because it is very cheap; it will cost more than a good article in the end.

In cutting rubber for gaskets, etc., have a dish of water handy, and keep wetting the knife-blade; it makes the work much easier.

Don't forget that there is no economy in employing a poor fireman. He c[illegible] and probably will, waste more coal than would pay the wages of a fir[illegible] man.

An ordinary steam engine, having two cylinders connected at right[illegible] the same shaft, consumes one-third (⅓) more steam than a sin[illegible] engine, while developing only the same amount of power.

A fusible plug ought to be renewed every three months by removing the old metal and re-filling the case; and it should be scraped clean and bright on both ends every time that the boiler is washed out, to keep it in good working order.

When you try a gauge cock, don't jerk it open suddenly, for if the water happens to be a trifle below the cock, the sudden relief from pressure at that point may cause it to lift and flow out, deceiving you in regard to its height. Whereas, if you open it quietly, no lift will occur, and you ascertain surely whether there is water or steam at that level.

Always open steam stop-valves between boilers very gently, that they may heat and expand gradually. By suddenly turning on steam a stop-valve chest was burst, due to the expansive power of heat unequally applied. The same care is also recommended when shutting off stop-valves. A fearful explosion once occurred by shutting a communicating stop-valve too suddenly—due to the recoil.

In order to obtain the driest possible steam from a boiler, there should be an internal perforated pipe (dry pipe, so called) fixed near the top of the boiler, and suitably connected to the steam pipe. The perforations in this pipe should be from one-quarter to one-half greater in area than that of the steam pipe. Domes are of no use as steam driers; they only add a very little to the steam space of a boiler, and are often a source of loss by radiation.

If a glass gauge tube is too long, take a triangular file and wet it, hold the tube in the left hand, with the thumb and forefinger at the place where you wish to cut it, saw it quickly and lightly two or three times with the edge of the file, and it will mark the glass. Now take the tube in both hands, both thumbs being on the opposite side to the mark, and an inch or so apart, and then try to bend the glass, using your thumbs as fulcrums, and it will break at the mark, which has weakened the tube.

A stiff charge of coal all over a furnace will lower the temperature 200° or 300° in a very short time. After the coal is well ignited the temperature will rise about 500°, and as it continues burning will gradually drop about 200°, till the fireman puts in another charge, when the sudden fall before mentioned takes place again. This sudden contraction and expansion frequently causes the bursting of a boiler, and it is for this reason that light and frequent charges of coal, or else firing only one-half of the furnace at a time should be always insisted upon.

Be careful when using a wrench on hexagonal nuts that it fits snugly, or the edges of the nut will soon become rounded.

Be careful how you use a monkey-wrench, for if it is not placed on the nut properly the strain will often bend or fracture the wrench.

The area of grate for a boiler should never be less than ⅛ of a square foot per indicated horse power of the engine, and it is seldom advisable to increase this allowance beyond ⅙ of a square foot per I. H. P.

The area of tube service for a boiler should not be less than 2¼ square feet per I. H. P. of the engine.

The ratio of heating surface to grate area in a boiler should be 30 to 1 as a minimum, and may often be increased to 40 to 1, or even more, with advantage.

Lap-welded pipe of the same rated size has always the same outside diameter, whether common, extra, or double extra, but the internal diameter is of course decreased with the increased thickness.

A good cement for steam and water joints is made by taking 10 parts, by weight, of white lead, 3 parts of black oxide of manganese, 1 part of litharge, and mixing them to the proper consistency with boiled linseed oil.

To harden a cutting-tool, heat it in a *coke* fire to a blood-red heat and plunge it into a solution of salt and water (1 pound of salt to 1 gallon of water), then polish the tool, heat it over gas, or otherwise, till a pale straw or gold color shows on the polish, and cool it in the salt water.

Small articles can be plated with brass by dipping them in a solution of 9¼ grains each, of sulphate of copper and chloride of tin, in 1¾ pints of water.

Don't be eternally tinkering about your engine, but *let well enough alone*.

Don't forget that with a copper hammer you can drive a key just as well as with a steel one, and that *it doesn't leave any marks*.

Keep on hand slips of thin sheet copper, brass and tin to use as liners, and if you shape some of them properly, much time will be saved when you need them.

A few wooden skewer-pins, such as butchers use, are very useful for many purposes in an engine-room. Try them.

In running a line of steam-pipe where there are certain rigid points, make arrangements for expansion on the line between those points, or you will come to grief.

Arrange the usual work of the engine and fire-rooms systematically, and adhere to it. It pays well.

Don't forget that cleanliness is next to Godliness.

Rubber cloth kept on hand for joints should be rolled up and laid away by itself, as any oil or grease coming in contact with it will cause it to soften and give out when put to use.

When using a jet condenser let the engine make three or four revolutions before opening the injection valve, and then open it gradually, letting the engine make several more revolutions before it is opened to the full amount required.

Open the main stop-valve before you start the fires under the boilers.

When starting fires don't forget to close the gauge-cocks and safety-valve as soon as steam begins to form.

An old Turkish towel cut in two lengthwise is better than cotton-waste for cleaning brass-work.

Always connect your steam-valves in such a manner that the valve closes against the constant steam pressure.

Turpentine well mixed with black varnish makes a good coating for iron smoke-pipes.

Ordinary lubricating oils are not suitable for use in preventing rust.

You can make a hole through glass by covering it with a thin coating of wax —by warming the glass and spreading the wax on it, scrape off the wax where you want the hole, and drop a little fluoric acid on the spot with a wire. The acid will cut a hole through the glass, and you can shape the hole with a copper wire covered with oil and rotten-stone.

A mixture of one ounce of sulphate of copper, one-quarter of an ounce of alum, half a teaspoonful of powdered salt, one gill of vinegar and twenty drops of nitric acid will make a hole in steel that is too hard to cut or file easily. Also, if applied to steel and washed off quickly, it will give the metal a beautiful frosted appearance.

BELTING AND VELOCITY OF PULLEYS.

Belts should not be made tighter than necessary. Over half the trouble from broken pulleys, hot boxes, etc., can be traced to the fault of tight belts, while the machinery wears much more rapidly than when loose belts are employed.

The speed of belts should not be more than 3,000 or 3,750 feet per minute.

The motion of driving should run with and not against the laps of the belts.

Leather belts should be run with the strongest or flesh side on the outside and the grain (hair) side on the inside, nearest the pulley, so that the strongest part of the belt may be subject to the least wear. It will also drive 30 per cent. more than if run with the flesh side nearest the pulley. The grain side adheres best because it is smooth. Do not expose leather belts to the weather.

When the length of a belt cannot be conveniently ascertained by measuring around the pulleys with a tape line, the following rule will be serviceable:

Add the diameters of the two pulleys together and divide by 2; multiply this quotient by 3¼, and to the product add twice the distance between the centres of the shafts; the sum will be the length required.

RULES FOR CALCULATING SPEED OF PULLEYS.

I.—The diameter of the driver and driven being given, to find the number of revolutions of the driven:

RULE.—Multiply the diameter of the driver by its number of revolutions, and divide the product by the diameter of the driven; the quotient will be the number of revolutions.

II.—The diameter and the revolutions of the driver being given to find the diameter of the driven, that shall make any given number of revolutions in the same time:

RULE.—Multiply the diameter of the driver by its number of revolutions, and divide the product by the number of revolutions of the driven; the quotient will be its diameter.

III.—To ascertain the size of the driver:

RULE.—Multiply the diameter of the driven by the number of revolutions you wish to make, and divide the product by the revolutions of the driver; the quotient will be the size of the driver.

The above rules are practically correct. Though, owing to the slip, elasticity, and thickness of the belt, the circumference of the driven seldom runs as fast as the driver.

Belts, like gears, have a pitch-line, or a circumference of uniform motion. This circumference is within the thickness of the belt, and must be considered if pulleys differ greatly in diameter, and an accurate record of speed is absolutely necessary.

USEFUL MEMORANDA.

Mean circumference of the earth	24,856 miles.
Diameter of the earth	7,921 "
Radius of the equator	20,921,180 feet.
Polar semi-axis	20,853,180 "
Length of geographical or nautical mile	6075·66 "
Ratio of nautical to English mile	1·15068 to 1.
Length of pendulum at the equator	39·01326 inches.
Length of pendulum at New York	39·10153 "
Force of gravity at New York, feet per second	32·1594
Tropical year	365·242245 days.
Length of an arc =	No. of deg. × rad. × ·01745.
Circumference of a circle	Diam. × 3·1416.
Area of do	Diam.^{2} × ·7854.
Diameter of do	Cir. × ·31831.
Side of an equal square	Diam. × ·8862.
Diameter of equal circle	$\sqrt{\text{Area}}$ × 1·12837.
Ellipse, area	T. axis × C. axis × ·7854.
Sphere, surface	Diam.^{2} × 3·1416.
" solidity	Diam.^{3} × ·5236.
Square feet	Circular inches × ·00456.
" "	Square inches × ·00695.
" yards	Square feet × ·111.
Cubic feet	Cubic inches × ·00058.
" yards	Cubic feet × ·03704.
" "	Cylindrical feet × ·02909.
English miles	Lineal feet × ·00019, or lineal yards × ·000568.
" acres	Square yards × ·00026067.
Parabola, area	⅔ of base × height.
1 square foot	183·346 circular inches.
Cubic inches in imperial gallon	277·274.
" " in standard U. S. gal.	231.
" " in beer gallon	282.
" foot	6·232 imperial gallons.
" inches × ·028848	pints.
" " × ·014424	quarts.
" " × ·003606	gallons.
" " × ·0004508	bushels.
" " × ·00005635	quarters.
" " × ·0005787	cubic feet.
" " × ·0000214	" yards.
" " × ·0163	French litres.
" " × ·257	1 lb cast iron.
" " × ·278	1 lb wrought iron.
" " × ·491	1 lb quicksilver.
" " × ·4112	1 lb lead.
" " × ·2632	1 lb tin.
" " × ·2597	1 lb zinc.
" " × ·3201	1 lb copper.
" " × ·3058	1 lb brass.
Statute acres × 4840	square yards.
Square links × ·4356	" feet.
" feet × 2·3	" links.
Links × ·22	yards.
" × ·66	feet.
Feet × 1·5	links.
Cubic feet × 2·200	cylindrical inches.
Cylind. inches × ·0004546	cubic yards.
Imperial gallons × ·1604	" feet.
Standard gallons × ·1331	" feet.
Cubic feet × ·779	bushels.
Bushels × ·0476	cubic yards.
" × 1·284	" feet.
" × 2218·2	" inches.
Statute miles × ·869	mean geographical miles.

Pounds avoir. × 7000	grains.
Grains × ·0001429	pounds avoirdupois.
Pounds avoir. × ·009	cwts.
" " × ·00045	tons.
Tons × 2·240	pounds avoirdupois.
" × ·984	tonnes, French.
Pounds on the square inch × ·144	pounds on the square foot.
" " " foot × ·007	" " inch.
Miles per hour × 1·467	feet per second.
Feet per second × ·682	miles per hour.
French metres × 3·281	English feet.
" litres × ·2201	imperial gallons.
" hectolitre × 2·7512	English bushels.
" grammes × ·002205	pounds avoirdupois.
" kilogrammes × 2·205	" "
Dia. of sphere × ·806	dimensions of equal cube.
" " × ·6667	length of equal cylinder.
One atmosphere	14·7 pounds on the square inch.
"	21·16 " " " foot.
"	29·922 inches of mercury.
"	33·9 feet of water.
Barrel of tar	26¼ gallons.
Cable's length	240 yards.
Cask of black lead	1½ cwt.
English Chaldron of coal	25½ cwt.
" " coke	12½ to 15 cwt.
Chaldron of coal, heaped measure	36 bushels.
Cord of wood	128 cubic feet.
Dozen	12 articles.
Fagot of steel	120 pounds.
Fodder of lead	19½ cwt.
Gross	12 dozen.
Great gross	12 gross.
Bushel of wheat	60 pounds.
" indian corn	56 "
" oats	32 "
" rye	56 "
" wheat bran	20 "
Firkin of butter	56 "
Quintal of dry salt fish	100 "
Cask of raisins	100 "
Barrel of flour	196 "
Barrel of beef, pork or fish	200 "
Pig of ballast	56 "
Quire of paper	24 sheets.
Ream of paper	20 quires or 480 sheets.
Bundle	2 reams.
Bale	5 bundles.
Roll of parchment	60 skins.
Score	20 articles.

THE FEEDING PROPERTIES OF DIFFERENT VEGETABLES,

In comparison with 10 lbs. of hay.

Hay	10	Carrots	35
Clover hay	8	Cabbage	30 to 40
Vetch hay	4	Peas and beans	2 to 3
Wheat straw	52	Wheat	5
Barley straw	52	Barley	6
Oat straw	55	Oats	5
Pea straw	6	Rye	5
Potatoes	28	Indian corn	6
Old potatoes	40	Bran	5
Turnips	60	Oil-cake	2

Thus, 2 lbs. of oil-cake is worth as much as 55 lbs. of oat straw.

USEFUL INFORMATION.

In Kentucky, 80 lbs. of bituminous or cannel coal make a bushel.
In Illinois, 80 lbs. of bituminous coal make a bushel.
In Missouri, 80 lbs. of bituminous coal make a bushel.
In Indiana, 70 lbs. of bituminous coal make a bushel.
In Pennsylvania, 76 lbs. of bituminous coal make a bushel.

Coal, corn in the ear, fruit and roots are sold by heaped measure, that is, the bushel is heaped in the form of a cone, which cone must be 19⅛ ins. in diameter (equal to the outside diameter of the standard bushel measure), and at least 6 ins. in height.

Grain and some other commodities are sold by stricken measure, that is, the measure is to be stricken with a round stick or roller, straight and of the same diameter from end to end.

Glazing and stone-cutting are estimated by the square foot.

CHEMICAL MEMORANDA.

A simple or elementary substance is a body that cannot be resolved or separated into any simpler substances—as oxygen, carbon, iron.

A compound substance is one consisting of two or more constituents—as water, carbonic acid gas, olefiant gas.

The equivalent number or atomic weight expresses the relations that subsist between the different proportions by weight in which substances unite chemically with each other.

The equivalent of a compound is the sum of the equivalents of its constituents.

Specific gravity expresses the difference that subsists between the weights of equal volumes of bodies.

So far as chemists have been able to discover, there are about 65 elementary or simple substances.

No compound body contains all the elementary substances. Most compounds are composed of two, three or four elements.

TABLE OF ELEMENTARY SUBSTANCES.

Names of Elements.	Symbol.	Atomic Weight.	Names of Elements.	Symbol.	Atomic Weight.
Aluminum	Al	27·4	Nickel	Ni	58·8
Antimony	Sb	122	Niobium	Nb	95
Arsenic	As	75	Nitrogen	N	14
Barium	Ba	137	Osmium	Os	199
Beryllium	Be	9·4	Oxygen	O	16
Bismuth	Bi	210	Pallidium	Pd	106·6
Boron	B	11	Phosphorus	P	31
Bromine	Br	80	Platinum	Pt	197·4
Cadmium	Cd	112	Potassium	K	39·1
Calcium	Ca	40	Rhodium	R	104
Carbon	C	12	Rubidium	Rb	85
Cerium	Ce	92	Ruthenium	Ru	104
Chlorine	Cl	35·5	Selenium	Se	79
Chromium	Cr	52·2	Silicium or Silicon	Si	28
Cobalt	Co	58·8	Silver	Ag	108
Copper	Cu	63·4	Sodium	Na	23
Fluorine	F	19	Strontium	Sr	87·6
Gold	Au	197	Sulphur	S	32
Hydrogen	H	1	Tantalum	Ta	182
Indium	In	74	Tellurium	Te	128
Iodine	I	127	Thallium	Tl	204
Iridium	Ir	198	Thorium	Th	231·5
Iron	Fe	56	Tin	Sn	118
Lanthanum	Ln	93	Titanium	Ti	50
Lead	Pb	207	Tungsten	W	184
Lithium	Li	7	Uranium	U	120
Magnesium	Mg	24	Vanadium	V	51·2
Manganese	Mn	55	Yttrium	Y	61·7
Mercury	Hg	200	Zinc	Zn	65
Molybdenum	Mo	96	Zirconium	Zr	89·6

LIST OF SOME BINARY COMPOUNDS.

Name of Compound.	Symbol.	
Ammonia	N	H_3
Bisulphide of Carbon	C	S_2
Carbonic acid gas	C	O_2
Carbonic oxide	C	O
Cyanogen	N	C_2
Hydrochloric acid	H	Cl
Light carbureted hydrogen	C	H_4
Nitric acid	N	O_5
Olefiant gas	C_2	H_4
Peroxide of iron	Fe_2	O_3
Protoxide of iron	Fe	O
Sulphurous acid gas	S	O_2
Sulphuric acid	H_2	SO_4
Sulphureted hydrogen	H_2	S
Water	H_2	O

NOMENCLATURE.

The compounds of the non-metallic elements with the metals and with each other have names ending in "ide" or "uret;" as Fe S, sulphide or sulphuret of iron.

When two or more equivalents of the non-metallic elements enter into combination, the number of equivalents is expressed by prefixes.

Bi means 2 eq., as $N\ O_2$ binoxide of nitrogen.
Ter " 3 eq., as $Sb_2\ S_3$ tersulphide of antimony.
Penta " 5 eq.,
Sesqui " 1½ eq. (= 2 to 3), as $Fe_2\ O_3$ sesquioxide of iron.
Proto " first, or 1 to 1, as Fe O protoxide of iron.
Sub " under, as Cu_2 O suboxide of copper.
Per ". the highest, as Cl O_4 protoxide of chlorine.

Alkalies neutralize acids, forming salts.

The terminations "ic" and "ous" are used for acids, the former representing a higher state of oxidation than the latter.

When a substance forms more than two acid compounds, the prefixes "hypo," *under*, and "hyper," *above*, are used.

A base is a compound which will chemically combine with an acid.

A salt is a compound of an acid and a base.

When water is in combination with acids or bases, they are said to be hydrated.

COMMON NAMES OF CERTAIN CHEMICAL SUBSTANCES.

Aqua fortis	Nitric acid.
Bluestone, or blue vitriol	Sulphate of copper.
Calomel	Chloride of mercury.
Chloroform	Chloride of formyle.
Common salt	Chloride of sodium.
Copperas, or green vitriol	Sulphate of iron.
Corrosive sublimate	Bichloride of mercury.
Dry alum	Sulphate of alumina and potash.
Epsom salts	Sulphate of magnesia.
Ethiops mineral	Black sulphide of mercury.
Galena	Sulphide of lead.
Glauber's salts	Sulphate of soda.
Iron pyrites	Bisulphide of iron.
Jeweler's putty	Oxide of tin.
King's yellow	Sulphide of arsenic.
Laughing gas	Protoxide of nitrogen.
Lime	Oxide of calcium.
Lunar caustic	Nitrate of silver.
Mosaic gold	Bisulphide of tin.
Nitre, or salt petre	Nitrate of potash.
Oil of vitriol	Sulphuric acid.
Realga	Sulphide of arsenic.
Red lead	Oxide of lead.
Rust of iron	Oxide of iron.
Soda	Oxide of sodium.

Spirit of hartshorn.......... :.......	Ammonia.
Spirit of salt..........................	Hydrochloric acid.
Stucco, or plaster of Paris.......	Sulphate of lime.
Sugar of lead............	Acetate of lead.
Vermillion.................	Sulphide of mercury.
Vinegar...............	Acetic acid.
Volatile alkal..................	Ammonia.
Water......	Oxide of hydrogen.
White vitriol............	Sulphate of zinc.

THE WEIGHT OF DIFFERENT SUBSTANCES.

Name of Body.	Weight of a cubic foot.		Weight of a cubic inch.		No. of cubic inches in a lb.	Weight of a cubic yard in tons.
	In oz. 1.	In lbs. 2.	In oz. 3.	In lbs. 4.	5.	6.
Platina........	19500	1218·75	11·284	·7053	1·417	....
Copper, cast....... ..	8788	549·25	5·086	·3178	3·146	....
Copper, sheet......	8915	557·18	5·159	·3225	3·103	....
Brass, cast.........	8396	524·75	4·852	·3037	3·293	....
Iron, cast	7271	454·43	4·203	·263	3·802	....
Iron, bar..........	7631	476·93	4·410	·276	3·623	....
Lead..............	11344	709·00	6·456	·4103	2·437	....
Steel, soft..........	7833	489·56	4·527	·2833	3·530	....
Steel, hard.........	7816	488·50	4·517	·2827	3·537	....
Zinc, cast..........	7190	449·37	4·156	·26	3·845	....
Tin, cast...........	7292	455·75	4·215	·2636	3·790	....
Bismuth............	9880	619·50	5·710	·3585	2·789	....
Gun Metal.........	8784	549·00	5·0775	·3177	3·147	....
Sand..............	1520	95·00	·8787	·055	18·190	1·145
Coal.....	1250	78·12	·7225	·0452	22·120	0·941
Brick	2000	125·00	1·156	·0723	13·824	1·506
Stone, paving......	2416	151·00	1·396	·0873	11·443	1·820
Stone, Bristol......	2554	159·62	1·478	·0923	10·825	1·924
Grindstone.....	2143	133·94	1·240	·07751	12·901	1·614
Chalk, British......	2781	173·81	1·609	·1005	9·941	2·095
Jet...............	1259	78·69	0·729	·04553	21·959	0·948
Salt..............	2130	133·12	1·233	·07704	12·980	1·604
Slate.............	2672	167·00	1·544	·0967	10·347	2·012
Marble........	2742	171·37	1·585	·0991	10·083	2·065
White Lead.... ...	3160	197·50	1·826	·1143	8·750	....
Glass.............	2880	180·00	1·664	·1042	9·600	....
Tallow....	945	59·06	·5462	·0342	29·258	....
Cork............	240	15·00	·138	·0087	115·200	....
Larch............	544	34·00	·315	·0197	50·823	....
Elm..............	556	34·75	·321	·0201	49·726	....
Pine, Pitch.....	660	41·25	·382	·024	41·890	....
Beech............	696	43·50	·403	·0252	39·724	....
Teak.............	745	46·56	·431	·027	37·113	....
Ash..	760	47·50	·440	·0275	36·370	....
Mahogany	852	53·25	·493	·0308	32·449	....
Oak	970	60·62	·561	·0351	28·505	....
Oil of Turpentine..	870	54·37	·503	·0315	31·771	....
Olive Oil.........	915	57·18	·529	·0331	30·220	....
Linseed Oil........	932	58·25	·539	·0337	29·665	....
Spirits, proof......	927	57·93	·536	·03352	29·288	....
Water, distilled....	1000	62·50	·578	·03617	27·648	0·753
Water, sea.........	1028	64·25	·594	·0372	26·894	0·774
Tar..............	1015	63·43	·587	·0367	27·242	....
Vinegar.......	1026	64·12	·593	·037	26·949	....
Mercury (at 60°)...	13568	848·00	7·851	·4908	2·037	....

BOARD MEASURE.

In board measure all boards are assumed to be 1 inch in thickness.

Breadth. Inches.	Area of a lineal ft.	Breadth. Inches.	Area of a lineal ft.	Breadth. Inches.	Area of a lineal ft.
¼	·021	4¼	·354	8¼	688
½	·042	4½	·375	8½	·708
¾	·063	4¾	·396	8¾	·729
1	·083	5	·417	9	·75
1¼	·104	5¼	·438	9¼	·771
1½	·125	5½	·458	9½	·792
1¾	·146	5¾	·479	9¾	·813
2	167	6	·5	10	·833
2¼	·188	6¼	·521	10¼	·854
2½	·208	6½	·542	10½	·875
2¾	·229	6¾	·563	10¾	·896
3	·25	7	·583	11	·917
3¼	·271	7¼	·604	11¼	·938
3½	·292	7½	·625	11½	·958
3¾	·313	7¾	·646	11¾	·979
4	·333	8	·667	12	1·

Area of a lineal foot multiplied by length in feet will give superficial contents in square feet.

To Compute Volume of Square Timber.

When all the dimensions are in feet:

RULE.—Multiply the breadth by the depth and that product by the length, and the product will give the volume in cubic feet.

When either of the dimensions are in inches:

RULE.—Multiply as above and divide by 12.

When any two of the dimensions are in inches:

RULE.—Multiply as before and divide by 144.

ROUND TIMBER.—TABLE OF ¼ GIRTHS.

¼ Girths. Inches.	rea in ft.	¼ Girths. Inches.	Area in ft.	¼ Girths. Inches.	Area in ft.
6	·250	12¼	1·04	19	2·50
¼	·272	½	1·08	½	2·64
½	·294	¾	1·12	20	2·77
¾	·317	13	1·17	½	2·91
7	·340	¼	1·21	21	3·06
¼	·364	½	1·26	½	3·20
½	·390	¾	1·31	22	3·36
¾	·417	14	1·36	½	3·51
8	·444	¼	1·41	23	3·67
¼	·472	½	1·46	½	3·83
½	·501	¾	1·51	24	4·
¾	·531	15	1·56	½	4·16
9	·562	¼	1·61	25	4·34
¼	·594	½	1·66	½	4·51
½	·626	¾	1·72	26	4·69
¾	·659	16	1·77	½	4·87
10	·694	¼	1·83	27	5·06
¼	·730	½	1·89	½	5·25
½	·766	¾	1·94	28	5·44
¾	·803	17	2·	½	5·64
11	·840	¼	2·09	29	5·84
¼	·878	½	2·12	½	6·04
½	·918	¾	2·18	30	6·25
¾	·959	18	2·25		
12	1·	½	2·37		

Area corresponding to ¼ girth (mean) in inches multiplied by length in feet = solidity in feet and decimal parts.

TABLE OF CUBIC YARDS OF EXCAVATION IN TRENCHES PER LINEAL FOOT.—SIDES VERTICAL.

Width in Feet.	Depth of Trench in Feet.						
	1	2	3	4	5	6	7
1·0	0·037	0·074	0·111	0·148	0·185	0·222	0·259
·5	0·055	0·111	0·166	0·222	0·277	0·333	0·388
2·0	0·074	0·148	0·222	0·296	0·370	0·444	0·518
·5	0·092	0·185	0·274	0·370	0·463	0·555	0·644
3·0	0·111	0·222	0·333	0·444	0·555	0·666	0·777
·5	0·129	0·259	0·388	0·518	0·648	0·777	0·876
4·0	0·148	0·296	0·444	0·592	0·740	0·888	1·037
·5	0·166	0·333	0·500	0·666	0·833	1·000	1·166
5·0	0·185	0·370	0.555	0·740	0·926	1·111	1·296
·5	0·203	0·406	0·611	0 815	1·015	1·222	1·426
6·0	0·222	0·444	0·666	0·888	1·111	1·333	1·555
·5	0·240	0·481	0·722	0·963	1·203	1·444	1·685
7·0	0·259	0·518	0·778	1·037	1·296	1·555	1·814
·5	0·277	0·555	0·844	1·111	1·388	1·666	1·944
8·0	0·296	0·592	0·888	1·185	1·481	1·777	2·074
·5	0·314	0·628	0·903	1·259	1·574	1·888	2·203
9·0	0·333	0·666	1·000	1·333	1·666	2·000	2·333
·5	0·351	0·703	1·055	1·407	1·759	2·111	2·462
10·0	0·370	0·740	1·111	1·481	1·852	2·222	2·592

Width in Feet.	Depth of Trench in Feet.							
	8	9	10	11	12	13	14	15
1·0	0·296	0·333	0·370	0·407	0·444	0·481	0·518	0·555
·5	0·444	0·500	0·555	0·611	0·666	0·722	0·777	0·833
2·0	0·592	0·666	0·740	0·815	0·888	0·962	1·037	1·111
·5	0·740	0·833	0·926	1·018	1·111	1·203	1·288	1·388
3·0	0·888	1·000	1·111	1·222	1·333	1·444	1·555	1·666
·5	1·036	1·166	1·296	1·425	1·555	1·654	1·752	1·944
4·0	1·185	1·333	1·481	1·628	1·777	1·926	2·074	2·222
·5	1·333	1·500	1·666	1·833	2·000	2·166	2·333	2·500
5·0	1·481	1·666	1·851	2·037	2·222	2·407	2·592	2·777
·5	1·630	1·833	2·037	2·237	2·444	2·648	2·852	3·055
6·0	1·777	2·000	2·222	2·444	2·666	2·888	3·111	3·333
·5	1·936	2·166	2·407	2·647	2·888	3·130	3·370	3·611
7·0	2·074	2·333	2·592	2·851	3·111	3·370	3·629	3·888
·5	2·222	2·500	2·777	3·055	3·333	3·611	3·888	4·166
8·0	2·370	2·666	2·963	3·258	3·555	3·851	4·148	4·444
·5	2·518	2·833	3·148	3·462	3·777	4·092	4 406	4·722
9·0	2·666	3 000	3·333	3·666	4·000	4·333	4·666	5·000
·5	2·814	3·166	3·518	3·870	4·222	4·573	4·924	5·277
10·0	2·963	3·333	3·703	4·073	4·444	4·814	5·184	5·555

CONTENTS (BOARD MEASURE) OF 1 LINEAL FOOT OF TIMBER.

Br'th in in.	Thickness in inches.												
	2	3	4	5	6	7	8	9	10	11	12	13	14
18	3·	4·5	6·	7·5	9·	10·5	12·	13·5	15·	16·5	18·	19·5	21·
17	2·83	4·25	5·66	7·08	8·5	9·92	11·33	12·75	14·17	15·58	17·	18·42	19·83
16	2·67	4·	5·33	6·67	8·	9·33	10·67	12·	13·33	14·67	16·	17·33	18·66
15	2·5	3·75	5·	6·25	7·5	8·75	10·00	11·25	12·5	13·75	15·	16·25	17·5
14	2·33	3·5	4·67	5·83	7·	8·17	9·33	10·5	11·67	12·83	14·	15·17	16·33
13	2·17	3·25	4·33	5·42	6·5	7·58	8·67	9·75	10·83	11·92	13·	14·08	
12	2·	3·	4·	5·	6·	7·	8·	9·	10·	11·	12·		
11	1·83	2·75	3·67	4·58	5·5	6·42	7·33	8·25	9·17	10·08			
10	1·67	2·5	3·33	4·17	5·	5·83	6·67	7·5	8·33				
9	1·5	2·25	3·	3·75	4·5	5·25	6·	6·75					
8	1·33	2·	2·67	3·33	4·	4·67	5·33						
7	1·17	1·75	2·33	2·92	3·5	4·08							
6	1·	1·5	2·	2·5	3·								
5	·83	1·25	1·67	2·08									
4	·67	1·	1·33										
3	5	·75											
2	·33												

To ascertain contents of piece of timber. Find in the table the contents of one foot and multiply by the length in feet of the piece.

Example: What is the contents of a piece of timber 10×11·20 feet long? 9·17×20=183·4 feet B. M.

TABLE

SHOWING THE NUMBER OF VOLUMES OF VARIOUS GASES WHICH 100 VOLUMES OF WATER, AT 60° FAHR. AND 30 INCHES BAROMETRIC PRESSURE, CAN ABSORB.

(*Dr. Frankland.*)

Ammonia	7800	volumes.
Sulphurous acid	3300	"
Sulphureted hydrogen	253	"
Carbonic acid	100	"
Olefiant gas	12·5	"
Illuminating hydrocarbons	Not determined, but probably more soluble than olefiant gas.	
Oxygen	3·7	volumes.
Carbonic oxide	1·56	"
Nitrogen	1·56	"
Hydrogen	1·56	"
Light carbureted hydrogen	1·60	"

When water has been saturated with one gas and is exposed to the influence of a second, it usually allows a portion of the first to escape, whilst it absorbs an equivalent quantity of the second. In this way a small portion of a not easily soluble gas can expel a large volume of an easily soluble one.

ARITHMETICAL SIGNS USED IN THE POCKET-BOOK.

$+$ signifies *plus*, or addition.
$-$ " *minus*, or subtraction.
$\times$ " multiplication.
$\div$ " division.
$: \, :: \, :$ " proportion.
$=$ " equality.
$\sqrt{}$ " square root.
$\sqrt[3]{}$ " cube root, etc.

Thus,

$5 + 3$, denotes that 3 is to be added to 5.
$6 - 2$, denotes that 2 is to be taken from 6.
7×3, denotes that 7 is to be multiplied by 3.
$8 \div 4$, denotes that 8 is to be divided by 4.
$2 : 3 :: 4 : 6$, shows that 2 is to 3 as 4 is to 6.
$6 + 4 = 10$, shows that the sum of 6 and 4 is equal to 10.
$\sqrt{3}$, denotes the square root of the number 3.
$\sqrt[3]{5}$, denotes the cube root of the number 5.
7^2, denotes that the number 7 is to be squared.
8^3, denotes that the number 8 is to be cubed.

——————— The *Bar* denotes that the numbers or quantities are to be taken together: thus

$$\overline{6-2}+8=12, \text{ or } 5\times\overline{6+1}=35.$$

The same may be expressed by the ( ) Parentheses; as $(2+6)\times 4=32$.

A *Decimal Point* is a period (·) prefixed to a number to show that the number is less than unity (1); thus $\cdot 2=\frac{2}{10}$; $\cdot 35=\frac{35}{100}$; $5\cdot 75=5\frac{75}{100}$ or $5\frac{3}{4}$; $1\cdot 25=1\frac{25}{100}$ or $1\frac{1}{4}$; $\cdot 00375=\frac{375}{100000}$, etc.

Degrees are expressed by writing ° over them, as 24° for 24 degrees.

Minutes are marked by an accent (′).

Seconds, thus (″), etc. Thus, 30° 40′ 4″ is read 30 degrees, 40 minutes and 4 seconds. When used in dimensions the single mark denotes feet and the double mark inches. Thus, 4′ 6″ is 4 ft. 6 in.

ALGEBRAIC CHARACTERS.

Algebra is a method of investigating quantity by means of general characters called symbols. In addition to the arithmetical signs already given, the different letters of the alphabet are used to represent different quantities.

To illustrate algebraic symbols let l denote the length, b the breadth and h the heighth of a mine car, If it be desired to divide the height into the product of the length and breadth, it is expressed as follows:

$$\frac{lb}{h}$$

When two or more letters are placed together, without anything between them, it is understood that the quantities represented by those letters should be multiplied together. If l represents 8 and b 4, then 4 and 8 are multiplied together; thus, $4\times 8=32$.

If it be desired to divide the height into the sum of the length and breadth, it is thus expressed:

$$\frac{l+b}{h}$$

The square of the length multiplied by the cube of the breadth, thus:

$$l^2b^3$$

The square root of the length divided by the cube root of the breadth, thus:

$$\frac{\sqrt{l}}{\sqrt[3]{b}}$$

The square root of the difference of the length and breadth divided by the height, thus:

$$\frac{\sqrt{l-b}}{h}$$

The square root of the quotient of the sum and difference of the length and breadth, thus:

$$\sqrt{\frac{l+b}{l-b}}$$

GRAVITY.

(*From Molesworth.*)

N = Number of seconds.
S Space fallen through in feet.
V Velocity in feet per second, acquired in N seconds or S space.
V $N\times 32\cdot 2$.
V $\sqrt{S\times 64\cdot 4}=\cdot 8025\sqrt{S}$.
S $N^2 \times 16\cdot 1$.

These formulæ are approximate, varying with the latitude and elevation.

L = Latitude.
H   Elevation above sea level in feet.
R   Radius of earth in feet.
g Force of gravity, feet per second.
g 32·1899 at London at the level of the sea.

$$g \quad 32{\cdot}1695\,(1 - {\cdot}00284 \cos.\ 2\,L)\left(1 - \frac{2\,H}{R}\right)$$

If 2 lat. be obtuse, then—

$$g \quad 32{\cdot}1695 = [1 \times {\cdot}00284\,(\cos.\ 180 - 2\,L)]\left(1 - \frac{2\,H}{R}\right)$$

R = 20,923,000 at the equator.
20,853,000 at the poles.
20,888,000 mean radius.

CENTRIFUGAL FORCE.

W = Weight of revolving body in pounds.
R   Radius or distance from centre of motion.
N   Number of revolutions per minute.
F   Centrifugal force in pounds.
F $\cdot 00034\ W\ R\ N^2$.

$$W \quad \frac{2941\ F}{R\ N^2}$$

Momentum is the mass of any body, multiplied by its velocity in units of distance: for example, by feet per second.

Impulse is the force (say feet per second) multiplied by the time during which it acts.

VELOCITY DUE TO DIFFERENT HEIGHTS.

Fall in feet.	Velocity ft. per second.	Fall in feet.	Velocity ft. per second.	Fall in feet.	Velocity ft. per second.
1	8	50	57	275	133
2	11·3	60	62	300	139
3	13·9	70	67	325	144
4	16	80	72	350	150
5	18	90	76	375	155
10	25	100	80	400	160
15	31	125	90	450	170
20	36	150	98	500	179
25	40	175	106	550	188
30	44	200	113	600	196
35	47	225	120	800	227
40	51	250	127	1000	254

COAL DEALERS' COMPUTING TABLE FOR ASCERTAINING THE PRICE OF ANY NUMBER OF POUNDS, AT A GIVEN PRICE PER TON OF 2,000 POUNDS.

Lbs.	$0.75	$1.00	$1.25	$1.50	$1.75	$2.00	$2.25	$2.50	$2.75
10	·01	·01	·01	·01	·01	·01	·01	·01	·01
20	·01	·01	·01	·02	·02	·02	·02	·03	·03
30	·01	·02	·02	·02	·03	·03	·03	·04	·04
40	·02	·02	·03	·03	·04	·04	04	·05	·06
50	·02	·02	·03	·04	·04	·05	·06	·06	·07
60	·02	·03	·04	·05	·05	·06	·07	·08	·08
70	·03	·03	·04	·05	·06	·07	·08	·09	·10
80	·03	·04	·05	·06	·07	·08	·09	·10	·11
90	·03	·04	·06	·07	·08	·09	·10	·11	·12
100	·04	·05	·06	·08	·09	·10	·11	·13	·14
200	·08	·10	·13	·15	·17	·20	·23	·25	·28
300	·11	·15	·19	·23	·26	·30	·34	·38	·41
400	·15	·20	·25	·30	·35	·40	·45	·50	·55
500	·19	·25	·31	·38	·44	·50	·56	·63	·69
600	·23	·30	·37	·45	·53	·60	·68	·75	·83
700	·26	·35	·44	·53	·61	·70	·77	·88	·96
800	·30	·40	·50	·60	·70	·80	·90	1·00	1·10
900	·34	·45	·56	·68	·79	·90	1·01	1·13	1·24
1000	·38	·50	·63	·75	·88	1·00	1·13	1·25	1·38
1100	·41	·55	·69	·83	·96	1·10	1·24	1·38	1·51
1200	·45	·60	·75	·90	1·05	1·20	1·35	1·50	1·65
1300	·49	·65	·81	·98	1·14	1·30	1·46	1·63	1·79
1400	·52	·70	·88	1·05	1·22	1·40	1·58	1·75	1·93
1500	·56	·75	·94	1·13	1·31	1·50	1·69	1·88	2·06
1600	·60	·80	1·00	1·20	1·40	1·60	1·80	2·00	2·20
1700	·64	·85	1·06	1·28	1·49	1·70	1·91	2·13	2·34
1800	·68	·90	1·13	1·35	1·58	1·80	2·03	2·25	2·48
1900	·71	·95	1·19	1·43	1·66	1·90	2·14	2·38	2·61

Lbs.	$3.00	$3.25	$3.50	$3.75	$4.00	$4.25	$4.50	$4.75	$5.00
10	·02	·02	·02	·02	·02	·02	·03	·03	·03
20	·03	·03	·04	·04	·04	·05	·05	·05	·05
30	·05	·05	·05	·06	·06	·07	·07	·07	·08
40	·06	·07	·07	·08	·08	·09	·09	·10	·10
50	·08	·08	·09	·09	·10	·11	·12	·12	·13
60	·09	·10	·11	·11	·12	·13	·14	·15	·15
70	·11	·11	·12	·13	·14	·15	·16	·17	·18
80	·12	·13	·14	·15	·16	·17	·18	·19	·20
90	·14	·15	·16	·17	·18	·19	·20	·22	·23
100	·15	·16	·18	·19	·20	·22	·23	·24	·25
200	·30	·33	·35	·38	·40	·43	·45	·48	·50
300	·45	·49	·53	·56	·60	·64	·68	·72	·75
400	·60	·65	·70	·75	·80	·85	·90	·95	1·00
500	·75	·81	·88	·94	1·00	1·07	1·13	1·19	1·25
600	·90	·98	1·05	1·13	1·20	1·28	1·35	1·43	1·50
700	1·05	1·14	1·23	1·31	1·40	1·49	1·58	1·67	1·75
800	1·20	1·30	1·40	1·50	1·60	1·70	1·80	1·90	2·00
900	1·35	1·46	1·58	1·69	1·80	1·92	2·03	2·14	2·25
1000	1·50	1·63	1·75	1·88	2·00	2·13	2·25	2·38	2·50
1100	1·65	1·79	1·93	2·06	2·20	2·34	2·48	2·62	2·75
1200	1·80	1·95	2·10	2·25	2·40	2·55	2·70	2·85	3·00
1300	1·95	2·11	2·28	2·44	2·60	2·77	2·93	3·09	3·25
1400	2·10	2·28	2·45	2·63	2·80	2·98	3·15	3·33	3·50
1500	2·25	2·44	2·63	2·81	3·00	3·19	3·38	3·57	3·75
1600	2·40	2·60	2·80	3·00	3·20	3·40	3·60	3·80	4·00
1700	2·55	2·76	2·98	3·19	3·40	3·62	3·83	4·04	4·25
1800	2·70	2·93	3·15	3·38	3·60	3·83	4·05	4·28	4·50
1900	2·85	3·09	3·33	3·56	3·80	4·04	4·28	4·52	4·75

FAULTS.

By E. H. Lawall, C.E., E.M.

A fault generally means a fracture or disturbance of the earth's strata breaking the continuity of the beds.

There are several kinds of faults, *e. g.:*

Faults of Dislocation, *Fig.* 1.

Fig. 1.

Faults of Denudation, *Fig.* 2.

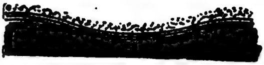


Fig. 2.

Faults of Upheaval, *Fig.* 3.

Fig. 3.

Trough Faults, *Fig.* 4.

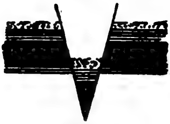


Fig. 4.

Reverse or Overlap Faults, *Fig.* 5.

Fig. 5.

Step Faults, *Fig.* 6.

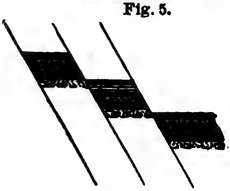


Fig. 6.

Thinning Out Faults, *Fig.* 7.

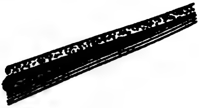


Fig. 7.

Faults of dislocation (*Fig.* 1) are sometimes of many hundred yards *throw* (the extent of the movement of the fault).

Faults of denudation (*Fig.* 2) are frequently of great extent, sometimes being several hundred yards in width and running through miles of country.

Faults of upheaval, trough faults and reverse faults are not of common occurrence; but step faults and thinning out faults are to be seen in almost every coal field.

When the contiguous *walls* (the rocks on the sides of the fracture) have been rubbed and ground together, so as to produce polished or grooved surfaces, the grooves show the direction of the movement, and the polished parts are called *slickensides*.

The wall of an inclined fault, vein, etc., toward the zenith, is the *hanging-wall*, *roof* or *top*; the opposite one is the *foot-wall*, *floor* or *bottom*.

The dip (inclination to a horizontal plane) of *beds* is normally 0°; of veins, faults and dykes it is usually in excess of 45°.

The *orientation* of a fault, bed, vein or dyke is the determination of its dip, and the magnetic bearing of the point toward which the horizontal side of the dip angle is directed.

Schmidt's Law.—In faulting, the hanging-wall of the fault has generally slipped down upon the foot-wall (See Fig. 8), and in meeting a fault, we find the faulted part by following the *obtuse angle*. From *a b* to find *c d*, we follow the angle *a b c* instead of *a b e*—while, in coming from *d*, we follow *d c b*. Faults generally agree with this law. Those, whose movement is contrary to this law, are called *reverse* faults.

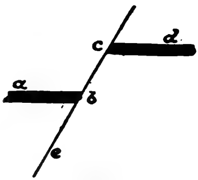


Fig. 8.

Problem.—*Having given the orientation of a fault and a bed, vein, etc., to find the nature of the movement of the faulted part of the same.*

In this case we consider the part of the bed, in which we are working, as the one that was stationary, though it may have been the one that moved, or though both walls of the fault may have had motion. On meeting the fault we examine its walls carefully, to ascertain whether any groovings exist. If we have met the fault at different levels in the bed or vein, and if our explorations are sufficiently extended, we may find sufficient evidence to solve this problem.

It frequently happens, however, that the earth-movement that produced fracture, separated the walls so that they were not contiguous during the movement of faulting, and the open space has been filled with detritus washed in from above, or with a decided vein formation.

In such cases we must depend upon other data than that considered in this problem. If, however, the walls have been contiguous during the faulting movement, we shall find grooves on the hard parts.

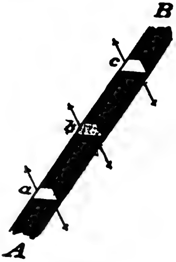


Fig. 9.

1. Let the plane of the paper represent the plane of the fault, and A B (*Figs.* 9, 10 and 11) be the trace of the intersection of the bed and fault. Let *a*, *b* and *c* be where the three levels (*Figs.* 9 and 10), on the bed, meet the fault. In *Fig.* 9 the groovings or striations, represented by the arrows, are found to be parallel to one another. In this case the faulted part moved in a straight line, each portion moving over an equal distance, and we shall find the faulted part in the direction of the arrows, either up or down. This movement is called a *straight fault*.

2. In *Fig.* 10 we find that the groovings or striations are not parallel to one another, but make different angles with A B. This shows that the fault is not a *straight* one, but has been produced by a rotary movement. Such are called *rotary faults.* If normals to the groovings drawn from *a*, *b* and *c*, intersect at R (*Fig.* 10), the groovings are shown to be circular, and the point R to be one of rest. Such a movement gives a *circular fault*, and at R *there is no faulting*, only a twisting of the strata.

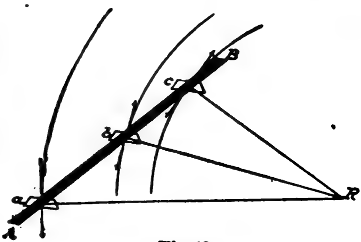


Fig. 10.

3. It frequently happens that we find more than one set of groovings at *a*, *b* and *c* (see *Fig.* 11), and that these sets may be arranged in groups, each group having a common center. If the various groovings have not obliterated one another and produced plane slickensides, we may be able to plot these groups as 111, 222, 333, in *Fig.* 11, and to find that these centers of rotation, R, R′, R″, are arranged on a straight line or curve of some sort

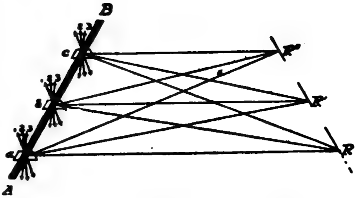


Fig. 11.

Such a movement produces a *trochoidal fault*, and *this is the usual mode of faulting.*

It frequently happens that the center of rotation is at such a distance from the place where the fault is studied, that the limited portions of the arcs of striations observed seem to be straight lines, and the movement is classed as a straight one. For a limited amount of throw this assumption will not cause great inaccuracy in subsequent work.

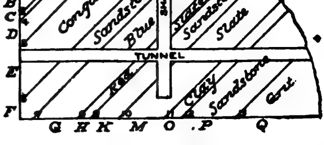
PROBLEM.—*Having given the orientation of a fault and a bed, and having ascertained the nature of the movement to find the direction in which to search for the faulted bed.*

We must form an accurate idea of the strata of the district. This is obtained by a study of outcrops: by sections of strata obtained along tunnels or shafts: or by cores from bore holes. From these data we obtain a knowledge of the order of succession of the various beds, and the thickness and nature of each stratum. We find that each has characteristics peculiar to itself, and when studied in connection with the rocks on either side of it, can be readily identified.

Rule.—If the fault outcrops, we can determine the stratum on each side of it, and, by a reference to our section, as determined above, ascertain at once the direction of the movement.

Rule.—If no outcrop occurs, we must study the rocks of the opposite wall of the fault, as we strike it in our underground work, and, by identifying them, learn the direction, as in the rule above.

To show how this will be done in either case, let us suppose that the following is the section shown by outcrops, by a tunnel, or by a shaft or vertical bore hole (*Fig.* 12). 1, 2, 3, etc., represent the junction planes between the beds. A, B, C, etc., represent the beds themselves.



Under the first rule given above, let us suppose that the hanging-wall of the outcropping fault gives sandstone B, while the other is in slate M. This shows that the hanging-wall has sunk, or the other risen, nearly the whole depth of the shaft.

Under the second rule given above let us suppose that the junction

while driving a level upon it we meet a fault, and find in the opposite wall of the fault slate A. This shows us that the opposite wall has sunk through the vertical distance between slate A and 9.

Rule.—If the fault be a straight one, there will be no difference in the dip of the strata of the walls of the fault; if the fault be rotary, the strata on either side of the fault will have different dips, and the difference will increase with the amount of rotation.

Rule.—If the center of rotation be in the foot-wall of the bed in which we are working, and we find the strata on the farther wall of the fault to have a dip greater than on the nearer wall, we must go down the fault to find the faulted part; if the strata have a lesser dip, we must go up the fault. If the center of rotation be in the hanging-wall of the bed, and the strata of the farther wall have a greater dip, we must go up the fault; if they have a lesser dip, we must go down.

This can be shown more compactly by the following:

	Strata on opposite wall of fault have— Greater dip.	Lesser dip.
Centre of rotation in hanging wall.	Go up the fault.	Go down the fault.
Centre of rotation in foot wall.	Go down the fault.	Go up the fault.

It frequently happens that the movement of faulting was accompanied by a great pressure of the walls together, so that the ends of the strata were bent during the sliding of the walls upon one another. In this case we shall find that the dip of the bed, in which we are working, varies suddenly as it approaches the fault, as in *Figs.* 13 and 14.

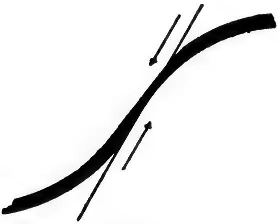


Fig. 13.

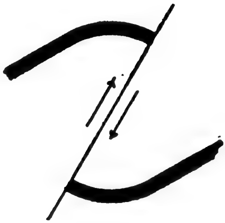


Fig. 14.

Rule.—In a fault, as just described, the strata "rise to the upthrow and dip toward the downthrow."

If, therefore, as we face the fault its plane passes under our feet and the bed in which we are working suddenly acquires a steeper dip, as it meets the fault, we go up (*Fig.* 13); if it becomes flatter, we go down (*Fig.* 14) If, however, the plane of the fault passes over our heads we must, in similar cases, go in opposite directions to those just given, as in *Figs.* 13 and 14.

SHOVED FAULTS.

Shoved faults, as well as the folding of strata and slip faults, are a result of the horizontal pressure arising in the sinking in of parts of the earth's crust. Under this term are to be understood those irregularities in which a part of the previously folded or erected strata, with the inclosed deposit, was torn off by another formation and shoved away. In such cases the strata and the deposits appear to be curved in the direction of the movement, and gradually drawn out even to disappearance, though no folding is observed in the vicinity of the shove, as occurs in folded faults. In addition, the plane of dislocation often exhibits traces of the movement in the shape of slickensides and striations.

PROSPECTING SHOVE FAULTS.

The principal signs by which one may recognize a fault as a shove fault, are, according to the foregoing paragraphs, the bending and gradual thinning out of

a deposit, without folding. If these signs are evident and not to be mistaken, we can consider, as a further means for recognizing a shove fault, *that the bending must always be taken, more or less, in the sense of a horizontally acting force.*

If an irregularity has been recognized as a shove fault, we can employ the following rule for reprospecting it, without using construction or calculation: *Cross the shode* (plane of dislocation) *and seek the shoved part of the deposit on that side toward which the bend is inclined.*

LODE DISRUPTIONS.

Lode disruptions appear under similar phenomena as slip faults, *i. e.*, a lode ceases on or in a fault, and continues on the other side, not however with the same strike, but with a lateral faulting. The lateral faulting is not, however, the result of the down-slip in the hanging-wall of the faulter, but is the result of circumstances connected with the original formation of the fissure.

A lode disruption corresponds completely to an ordinary change of strike, as occurs very often in lodes, and which is based upon the fact that the fissure-making force did not everywhere find the same cohesion in the solid country rock. There is, however, one difference between a lode disruption and an ordinary change of strike, which is, that in the former there is not always a continuity between the faulted parts of the lode. In regard to this last point it is to be observed that the disrupted lode appears badly fractured on one or both sides of the fault.

In most cases just this circumstance is sufficient for recognizing a fault as a disruption, for when the faulter is a decomposed dyke, which is often water-bearing (as also the line of faults in the coal formation), we can comprehend that the country rock in its vicinity was also decomposed, and that the fissuring force could cause fracturing at this point of the country rock. On the contrary, the circumstance that the faulted parts of the lode, if they are supposed to be shoved together, do not fit each other, is not a characteristic sign for a disruption, as the same appearance is met with also in shove faults.

The same is the case with the fine stringers or lode seams within the faulter, especially when the lode meets the faulter, not under an acute angle, but under an approximate right angle, and makes a hook-like bend before reaching the faulter.

A disruption can be judged with some probability only when the lode meets the faulter at an acute angle, and when the material composing the faulter is somewhat soft. If the angle is, for instance, a right angle, we cannot understand how cracks can run out against and across the direction of the pressure; and if the material of the faulter is hard, a disruption is improbable.

PROSPECTING OF A DISRUPTION.

In a fault, the formation of which was dependent upon such accidental circumstances as a change in the cohesion of an unfractured country rock, a rule for prospecting cannot be given. The little stringers which, lying near or in the faulter, connect the faulted parts of the lode, offer the sole suggestion.

Should no change of bearing be found, which must always be assumed in the bending of a lode before the faulter, but a shove fault, the purpose of the rule, viz., the prospecting of the faulted parts of the lode, would always be attained, but the question whether the fault belonged to the one or the other kind would be a theoretical one.

APPLICATIONS OF ELECTRICITY TO COAL MINING.

By FRANCIS A. POCOCK, M. E.

SIGNALING APPLIANCES.

Batteries.—Leclanche batteries in various forms can be bought at any establishment dealing in electric bells, etc. The Leclanche battery is composed of a glass vessel, in which is placed a zinc rod and a solution of sal-ammoniac and water, forming the positive pole, and a porous cell in which is a carbon plate packed tight with binoxide of manganese. When in good working order, the Electro-Motive Force (E. M. F.) of this battery is 1·46 volts.

To obtain the best results, the sal-ammoniac should nearly all be dissolved in

the water. As long as the water has a distinctly acid taste, there is nothing wrong with the solution; if it does not have this taste, add more sal-ammoniac. The zinc will coat with crystals; these should be removed by scraping and hot water. If the cell gets coated with crystals, it should be cleaned. If it gets red or rusty, it is worthless and should be thrown away. The binding posts must be kept clean. Make a practice of cleaning the battery often. Don't let the glass jar get covered with dust or white deposit; if this should occur, the jar is too full. Don't scrape the paraffine off the top of the jar; therefore don't wash jars in warm water. If the battery runs down quickly, there is trouble on the line.

The battery should be kept in a dry place, as it will work better. Each cell should have its own cover to prevent dust getting in. This is an open circuit battery and quickly runs down if there are grounds or there is much leakage on the wires. It is the battery most used in signalling and telephone work.

Gravity Batteries.—These are for closed circuits and not for open ones. They are composed of single large glass jars with a copper plate at the bottom, and an insulated wire attached to it passing through the fluid. Hanging in the jar is a plate of zinc with a terminal screw. The fluid is water in which is poured blue vitriol, making a deep blue solution. As long as the cell is doing its duty, the blue color remains, but dies out if there is anything wrong inside the cell. The zinc will, in time, become coated with a dark spongy matter. It should then be taken out and cleaned, even if the blue is still good. When the zinc wears out it should be replaced, and the cells should be kept well covered to keep out dust. The terminals should be kept clean and screwed down tight. If the battery is not connected right it will be less powerful.

Bells.—The bells should be frequently and carefully examined, not only when there is trouble on the line and you can get no signal, but at stated periods as well.

The binding posts should make good, firm and clean contact with the lead wires to the bell. The lead wires from the coil to the post must be in good order, as well as the wire entering the coil. The adjustment screw must be tight and not liable to work loose. The moving contact must be clean, both on the post and the spring. The adjustment must not be too hard or too light for the battery, and the armature screws must be firm.

Single stroke bells have one great advantage over vibrating bells, because the bell has not to break the circuit to make a sound. The line wire runs to one binding post, and the lead fastened to that post only goes through the coils and to the other binding post to which the return wire is attached; in this way there are fewer parts to get out of repair, and there is no place where a little bit of dirt can break the circuit. There is, however, one point in their use that must be remembered—that is, that galvanized iron or hard drawn copper wire is necessary, because the bare iron wire rusts too quickly in the damp air of the mine, and rust will prevent the bell working well or being reliable. A great advantage in signalling is that the single stroke bell gives a more definite signal than the vibrating bell.

Wire.—If the mine air is damp, it pays to put in a copper or phosphor bronze wire, because the iron wire (even if galvanized) will rust in time, and the signals are more or less deranged. One smash up will cost far more than the difference in the price of the wire, and it is false economy to save in this direction.

The wires, for there must be at least two, should be strung along the roof timbers, as in that position they are most out of the way of trouble from trips leaving the track, and are only in danger if the trip ends up. (As the trip-rider is usually on the rear end of the trip, this is of importance; for if the wires are broken, the break is between him and the engine and he can make no signal.) If the wires are broken and the ends fall together, the bell will ring until they are separated, and thus cause confusion in the engine house.

In stringing wires, enough slack should be left to allow the trip-rider to bring them together to make the signal. Too much care cannot be taken to prevent the wires from touching any of the wet timbers of the gangway. More than one system has been condemned because care had not been exercised in putting up the wires. If they touch the wet timbers, the batteries will run down, more or less, and there will be continual trouble. They should be run on insulators everywhere. Wood is always more or less wet, and is not to be trusted at all.

In running hard copper wire in the mines, do not let it kink; that will make it break. Do not use the hard wire as a binding wire. Be sure that every insulator is so placed that running water does not flow over it—it will make a ground in a very short time. Keep the wires an even distance apart and in the same relative position—the man can then find them in the dark. See that the wires cannot swing together by a mere touch, or it will make a false signal.

Faults and Testing.—The easiest fault to find is a break; usually the wire will hang right down and show itself. In repairing a break, see that the ends of each wire are clean; scrape them with a knife. Take three inches of each wire, bend the ends at right angles, and twist one wire around the other. Don't be satisfied by just hitching the wire together, for it will make trouble in a very short time. If possible, solder the joint at once—if not at once, as soon as possible.

Another fault is a *bad joint*. It is usually the product of a badly repaired break, and is much harder to find. The easiest way to find it is to put the ends of two short wires in your mouth, and touch the other ends to the two wires of the circuit. As soon as you pass the bad joint, the current will be much weaker, and by the strength of the current you can locate the trouble.

A *ground* is a leak in the insulation, and is the hardest fault to find. By watching carefully you can sometimes see where the leak is. If you cannot find it in this way, proceed as follows:—First find which wire the trouble is on. To do this, first disconnect one wire from the battery. Use the mouth wires by putting one end to the battery and the other to the rail or rope; if you get no current, try the other wire to the battery. The wire you get a current on is the grounded wire; follow along this wire until the current stops. You will then find it necessary to break the wire. If you get a current by putting the ends into your mouth, the ground is in front of you; if not, the ground is behind or nearer the battery. Do not make the breaks too close together. When you have located the ground within a few hundred feet, go over the wire carefully and try to see where the ground is. The less breaks you make, the better. Before looking for trouble of any kind, be sure it is not in the battery or bell. Test each part carefully.

It pays to put up the wires in sections, making the joints in dry places. The wooden base should be well dried, boiled in paraffine, and screwed in its place. The joint should be made by bending each end of each wire around a brass screw, and three copper washers should be used on each joint. There should be one washer on the wood, then the end of one wire, then another washer and the end of the other wire, and a washer on top of all. The screw should be well driven in, and you have a number of stations where you can test your wires at any time.

APPLICATION OF POWER.

The object of this section is to convey to colliery managers an appreciation of the measurements of electrical power, the relation of the different terms to each other, and their counter-parts in steam practice, as far as this can be done to illustrate the subject.

It must be borne in mind that the terms used in electrical practice were adopted in 1884, when people were just beginning to consider the possibility of the use of electricity as a means of transmitting power. To define the various items, they had to take the most constant forces then in use, and to give the powers developed in terms of the unit.

Steam and its power are conveyed to our minds in horse power—that is, a horse power is 33,000 lbs. raised one foot in one minute, and this is just as much as 33 lbs. raised 1,000 feet in a minute. Therefore, the horse power is 33,000 ft. lbs. per minute, and the horse power of electrical work is the same.

ELECTRICAL TERMS.

Accumulator—Storage or secondary battery, in which electricity has been carried and has been converted into chemical energy, being re-transformed into electricity when the battery is put to use for the purpose of furnishing energy or light.

Anode—The positive pole of a battery.

Arc—The space between the points of the carbons in an electric light or lamp which is bridged by the current represented by the flame.

Armature—The revolving arm of an electric generator.

Battery—A primary battery is one in which electricity is obtained through the decomposition of metals in chemical solutions. Zinc and copper may be the metals and sulphuric acid the chemical. Gold, silver, platinum, iron, or tin may also be used as the metals, and sal-ammoniac, bichromate of potash, nitric acid and sulphate of copper may also be used as the chemicals. The storage battery is a cell of acidulated water, containing, for example, plates of lead. This arrangement has an electric current directed into it, which it will give back in almost an equal quantity when the energy is wanted. There are various

methods and ways of making both primary and secondary or storage-batteries, but the above are the general principles governing their construction.

Brush—The copper string which connects with the commutator of a dynamo and gathers the electricity for the conductors.

Candle—Our unit of illuminating power.

Carbons—Rods of carbon are used in arc lights for first establishing the current, and then, when withdrawn, form the arc over which the electric flame leaps. They are made of powdered coke by a secret process.

Cell—The vessel in which chemical action produces electricity.

Circuit—The path along which an electric current travels.

Commutator—The collector of the electricity generated, and from which the fluid is taken by the brushes.

Condenser—An arrangement for collecting a large quantity of electricity on a small surface.

Conductivity—The comparative ability of a substance to convey a current of electricity.

Conductor—Conveyors of the electric current, silver being the best, and copper next, in conductivity.

Core—The iron that becomes magnetized in an electro-magnet. In helix, this iron is of the softest kind.

Current—The flow of electricity along a conductor. Its strength in amperes is found by dividing the electro-motive force in volts by the resistance in ohms.

Dynamo—Machine for converting mechanical power into electrical energy.

Electrode—A pole of a battery.

Electro-motive force—The power that constitutes or moves electricity.

Electro-magnet—The soft iron core around which insulated wire is wound. It becomes highly magnetized when the current is sent through the coil, and is much more powerful than a permanent magnet, but its magnetism is lost when the current is broken.

Farad—The unit of electrical capacity.

Galvanometer—An instrument for measuring an electric current and for detecting the presence of electricity.

Horse power, Electrical—A unit of power equalling 746 watts of electrical energy. A current of one ampere and 746 volts is an electrical horse power.

Induction—The property by which one body having electrical, galvanic, or magnetic polarity, causes it or induces it in another body without having actual contact. In other words, an impress of molecular force or conditions from one body on another without direct contact. An electric current in a wire induces currents in conductors parallel to it.

Insulators—Substances possessing high resistance, such as glass, vulcanized rubber, paraffine, etc. When covering a wire along which an electric current is passing, it prevents loss of power by conduction, and makes the wires heavily charged safer for handling.

Joule—The union of heat and work which is expended in forcing one coulomb through one ohm. It equals ·7373 foot pound.

Magnet—A magnetized piece of iron or steel, capable of attracting iron or steel bodies and of inducting electric currents.

Negative—The terminal of a generator, where the positive current returns after traversing its circuit. Negative electricity is an amount less than the substance would naturally contain.

Polarity—A magnet suspended so that its movements are unrestricted in any direction will turn one point to the North, the other to the South. Hence the North and South poles of the magnet.

Pole—The terminal of a generator.

Positive—The point of a generator where the positive current leaves it.

Potential—Appliable electro-motive force corresponding to pressure or head in hydraulics.

Power—The rate of doing work.

Resistance—The opposition that a current meets in traversing a conductor.

No one has been able to tell us what electricity is, and it has not assumed a bodily shape so far. Therefore it is only known by what it does; and, after all, this is the most satisfactory way to know anything. So far it has not been found in a serviceable form in nature. What we have to deal with is the electricity generated by the use of machinery, and which, after being sent to a given place, is turned into mechanical power. As in every other form of transmission of power, there is more or less waste, and what we have to consider are the causes, effect, and amount of this loss of power. To enable the reader to more readily grasp the subject, we will endeavor to give results, etc., in horse power, which we all understand. Electricity is a very subtile agent, and close

adjustment will give the best results, which means the least loss for the money invested

To appreciate this fully, and at the same time make things plain, it is necessary to understand and appreciate the names given to the different properties and the part that these properties play in the production of power.

The Ohm is the unit of resistance, and is equal to the resistance of a column of pure mercury, one square millimeter in section and 106 centimeters long, at the temperature of melting ice.

A copper wire, 95% pure, $^1/_{100}$ in. diam., or 0·0085 sq. in. area and 1,000 ft. long, will, at 60° Fahr., offer a resistance of 1·0068 ohms.

A German silver wire, 36 in. long and $^1/_{200}$ in. diam., at 60° Fahr., will offer a resistance of 1·12 ohms.

The Volt is the unit of pressure to overcome resistance. It is $^7/_{10}$ of the pressure exerted by a standard Daniell cell. * Sometimes this is spoken of as Electro-Motive Force (E. M. F.). The unit is the E. M. F. which has strength (pressure) enough to cause a current of one ampere to flow through a wire whose resistance is one ohm. Therefore the volt is the difference of potential (pressure) between two points. These may be on one wire, or between two wires of the same system, or between a wire and the ground, or between a wire of one system and a wire of another.

The Ampere is the unit of current or flow. It is the amount that one volt can force through one ohm. One ampere can deposit 4·025 grms. of silver per hour.

$$\frac{\text{Volts}}{\text{Ohms}} \text{ or using symbols, } \frac{E}{R} = \text{Amperes.}$$

The Coulomb is the expression of quantity or flow of one ampere in one second.

The Watt is the unit of power. It is the rate of doing work, either useful or waste. Useful in converting electricity into mechanical motion, the heating to incandescence the filament in the glow lamp, or in maintaining the arc of light (burning carbon) in the arc lamp; or waste in heating the conveying wires, the generator or the motor.

Watts = Volts × Amperes, Amperes × Amperes × Ohms, or Volts × Volts ÷ Ohms.

$$\frac{\text{Volts} \times \text{Amperes}}{746} = \frac{\text{Amperes} \times \text{Amperes}}{746} = \frac{\text{Volts} \times \text{Volts}}{746 \times \text{Ohms}} = \text{Horse-power.}$$

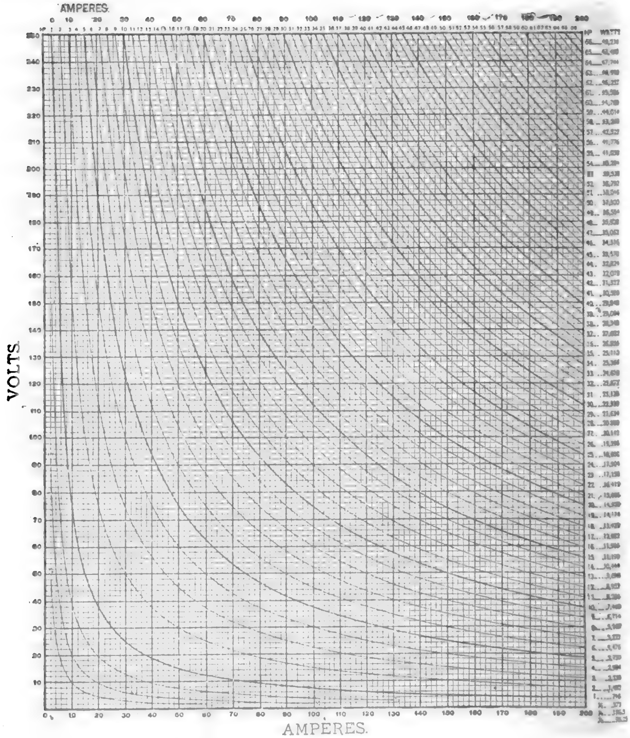
So we find that the watt is $^1/_{746}$ of one electrical horse-power, or 44·2359 foot-pounds per minute.

The units of electrical power, etc., are symbolized as follows:

Electro-motive force or volt	E. M. F.
Ampere or current	C.
Resistance or ohm	R.
Quantity or coulomb	Q.
Energy or joule	W.
Power or watt	P.

* The simplest Daniell cell is Sir W. Thomson's tray form, made of a square dish of sheet copper, 6″×6″×1½″ deep, into which is fixed, at ¾″ from the bottom, a flat zinc plate, having ¾″ clear between it and the copper. Sulphate of zinc solution (specific gravity, 1·02) is poured into the dish, then a definite quantity of a saturated solution of sulphate of copper is gently poured in, sufficient to raise the sulphate solution over the zinc. The cell is short-circuited a few minutes to deposit pure copper on the dish. When carefully made, the E. M. F. is from 1·072 to 1·075 volts.

It must be evident that there are a great many values of $\frac{C \times E}{746}$ equaling horse-power, and the calculation continually repeated is annoying and takes time, so we reproduce the valuable curves calculated by Mr. W. F. D. Crane, which will give, at a glance, any of the combinations from ⅛ to 66 H. P.



CRANE'S TABLE OF ELECTRICAL HORSE-POWER CHARACTERISTICS.

To show the method of using these curves, we give the following examples: Required the horse-power represented by volt meter showing 220, and the ampere meter showing 120.

Following the lines from 220 volts and from 120 amperes until they meet, and then the curve that crosses them at their intersection, we find that it leads out between 35 and 36, so that the H. P. is 35½.

A battery is said to give off 100 amperes and 20 volts. This is equivalent to nearly 3 horse-power.

A motor is receiving 20 amperes at 110 volts. This means that it is receiving 3 horse-power. These combinations may be carried on indefinitely up to 66 H. P., or 200 amperes and 247 volts. Again, if we are told that there are 24,618 watts being used, we know that it means $\frac{24,618}{746} = 33$ H. P.

But there is more in this table than we have yet shown. Suppose you want to run a motor of, say, 15 H. P., and the E. M. F. of your generator is 110 volts, by referring to the table of curves you find you will require 102 amperes of current. As there is a loss in the line of 10%, that will give 99 volts at the motor, so you will require 113 amperes of current.

In allowing for mechanical horse-power, there is a loss in the motor of some 10%, there is a loss in the gearing of about the same, and there is the loss in the line. Then there is loss in the generator, and the friction loss in the engine, all of which must be added up before you get the indicated horse-power of the engine that is necessary to drive the system and deliver the mechanical horse-power to the shaft that the motor drives and from which you wish to get the power.

Let us now take a case of transmission of power. Let us suppose that we require 20 H. P., and that it is to be applied 5,000 ft. away from the generator.

First we must provide for the losses in each part of the work; these will be about as follows:

Horse-power delivered,	20·000				
10% loss in the gear,	2·232	22·232			
10% " " motor,		2·48	24·712		
10% " " wire,			2·75	27·462	
10% " " generator,				3·05	30·51
10% " " engine,					3·40
Indicate horse-power required,					33·91

Therefore the efficiency will be.......... 58·8%
The losses will be........................ 41·2%

These losses will be { mechanical........................ 5·632
{ electrical........................ 8·27

Total losses.................................... 13·902 H. P.

To run 24·7 or, say, 25 H. P. at 500 volts. We look at the curve and find that it only goes to 250 volts. 25 H. P. at 250 volts requires 75 amperes, and it will take just half this at 500, or 37·5 amperes, or 18,650 watts. Therefore we know the current required. And if the E. M. F. at the motor is to be 500 volts, and the loss in the wire is 10%, the E. M. F. at the generator must be $500 + \frac{500}{90}$ or 555·5 volts, and the generator must give off 37·5 amperes $\times$ 555·5 volts or 20,831 watts, or a trifle less than 28 H. P.

The next thing to be settled is the wire to carry this current, and at the same time allow a loss of a little less than 10%.

We will suppose that we have not a table of circular mils. Then we have seen that $\frac{C \times C \times R}{746} = \text{H. P.}$, therefore $\frac{\text{H. P.} \times 746}{C \times C} = R$.

The H. P. which we want to lose in the wire is 2·75, and the C, 37·5. Then $\frac{2·75 \times 746}{37·5 \times 37·5} = 1·4581$ ohms for the total length of wire, and this must be twice the distance from generator to motor, or 10,000 feet, because the current must go and return.

Our resistance is 1·4581 ohms, and as the resistances are given per mile, we must multiply by the 5,280 ft. in one mile, and divide by the 10,000 ft. of line, which will give us 0·76986 ohms. By consulting the following table of resistances, we find that the nearest wire to this is a No. 3, and its resistance is 0·81254 ohms per mile, and that it weighs 0·203058 lbs. per ft., and that the 10,000 ft. will weigh 2030·6 lbs., and the resistance will be 1·5381 ohms.

Now the heat generated in the wire is the H. P. wasted, and our loss will be $\frac{C \times C \times R}{746}$ or $\frac{37·5 \times 37·5 \times 1·5381}{746} = 2·9$ H. P.

If we had taken a size larger wire, our loss would have been less than the limit of 2·75, but as the difference is 0·15 H. P., we used the No. 3 wire.

TABLE OF COPPER CONDUCTORS.

B. W. G., No.	Diam.	Area.	Copper Wire—Weight and Length.			
	Inch.	Circular Mils = d².	Pounds per foot.	Pounds per mile 1,760 yards.	Feet per pound.	Miles per pound.
0000	·454	206116	·623924	3294·32	1·60276	·000353058
000	·425	180625	·54676	2886·89	1·82895	·00034739
00	·380	144400	·437105	2307·92	2·28777	·0004333
0	·34	115600	·349928	1847·62	3·85773	·00054124
1	·300	90000	·272435	1438·43	3·6706	·00069519
2	·284	80656	·244151	1289·11	4·0958	·00077573
3	·259	67081	·203058	1072·15	4·9247	·0019327
4	·238	56644	·171465	905·333	5·8321	·00110457
5	·22	48400	·14651	773·56	6·8255	·0012927
6	·203	41209	·124742	658·638	8·0165	·0015183
7	·18	32400	·098076	517·844	10·1962	·0019311
8	·165	27225	·082411	435·235	12·1345	·0022981
9	·148	21904	·066305	350·089	15·0818	·0028564
10	·134	17956	·054354	286·99	18·398	·0034845
11	·12	14400	·04359	230·152	22·9413	·004345
12	·109	11881	·035964	189·893	27·805	·005266
13	·095	9025	·027319	144·245	36·6046	·0069326
14	·083	6889	·020853	110·1061	47·954	·009802
15	·072	5184	·015692	82·855	63·7267	·012069
16	·065	4225	·012789	67·6276	78·1902	·014809
17	·058	3364	·0101828	53·7665	98·203	·018589
18	·049	2401	·00726796	38·3748	137·590	·0260587
19	·042	1764	·00533972	28·1837	187·276	·035469
20	·035	1225	·00370815	19·579	269·676	·051075
21	·032	1024	·00309972	16·3665	322·610	·061100
22	·028	784	·00237312	12·5301	421·384	·0798078
23	·025	625	·0018919	9·9892	528·570	·100108
24	·022	484	·0014650	7·7357	682·55	·129271
25	·020	400	·00121082	6·39315	825·883	·156417
26	·018	324	·00098077	5·17844	1019·61	·193108
27	·016	256	·00077492	4·0916	1290·44	·24440
28	·014	196	·0005933	3·13264	1685·48	·31922
29	·013	169	·000511571	2·7011	1954·76	·370220
30	·012	144	·0004359	2·30152	2294·18	·434496

TABLE OF COPPER CONDUCTORS.

B. W. G., No.	Copper Wire—Length and Resistance.				Resistance and Weight.	
	Feet per ohm.	Miles per ohm.	Ohms per foot.	Ohms per mile.	Ohms per pound.	Pounds per ohm.
0000	19966·5	3·7815	·000050034	·264443	·000080272	12457·5
000	17497·15	3·31385	·000057152	·301763	·000104529	9668·7
00	13988·04	2·64925	·000071489	·377465	·000163553	6114·24
0	11198·17	2·12086	·000089300	·471505	·000255196	3928·56
1	8718·30	1·6512	·00011470	·60562	·00042102	2375·18
2	7813·50	1·47973	·00012799	·67580	·00052422	1907·59
3	6498·14	1·23071	·00015389	·81254	·00075786	1319·50
4	5487·107	1·03922	·000182245	·962256	·0010629	940·844
5	4688·51	·887975	·000213287	1·12616	·0014558	686·911
6	3991·91	·756044	·000250506	1·32267	·0020082	497·97
7	3138·59	·59443	·000318614	1·68228	·00324863	307·822
8	2637·29	·499486	·000379177	2·00206	·00460101	217·343
9	2121·84	·401864	·000471289	2·488405	·00710791	140·589
10	1739·40	·329432	·000574911	3·03553	·0105772	94·548
11	1394·93	·264191	·000716882	3·78514	·0164462	60·8042
12	1150·91	·217976	·000868875	4·58766	·0241593	42·392
13	874·252	·165578	·00114383	5·603945	·0418692	23·8839
14	667·338	·12639	·00149849	7·91203	·0718583	13·9163
15	502·175	·095109	·00199134	10·5142	·126788	7·8872
16	409·276	·077514	·00244334	12·9008	·191045	5·2344
17	325·871	·061718	·0030687	16·20274	·301355	3·31836
18	232·585	·04405	·0042995	22·7014	·59157	1·6904
19	170·879	·032363	·0058521	30·8991	1·09596	·912445
20	149·3915	·022475	·00842703	44·4947	2·28254	·44003
21	99·195	·018787	·01008116	53·2285	3·25229	·30748
22	75·9461	·014384	·0131672	69·5230	5·54848	·18023
23	60·5437	·011467	·0165170	87·2090	8·73038	·11454
24	46·8851	·008879	·02132874	112·616	14·5579	·068691
25	38·748	·007338	·025808	136·265	21·3142	·046917
26	31·3859	·005944	·03186144	168·229	32·4863	·030782
27	24·7987	·004696	·0403246	212·914	52·0367	·019217
28	18·9865	·003595	·05266892	278·092	88·7724	·011265
29	16·3710	·003100	·0610834	322·522	119·404	·008375
30	13·9493	·002641	·07168825	378·514	164·462	·006080

TO FIND THE COST OF CONDUCTORS TO CONVEY ANY HORSE POWER ANY DISTANCE

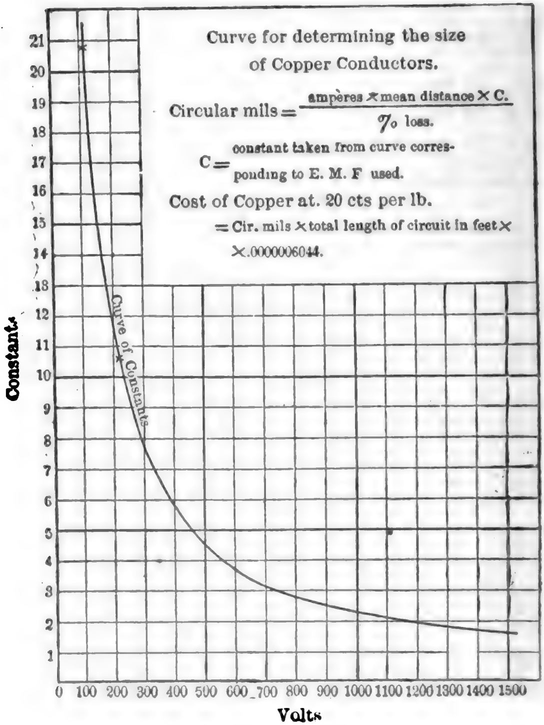
Mr. Lemuel W. Serrell, M. E., gives the following excellent rule for calculating the cost of conductors:

If a constant E. M. F. can be maintained at the motor terminals, any of the best motors on the market will work satisfactorily, if properly installed.

In considering the line work and the methods of distribution, the following cut shows a curve for determining the size of wire to use, to carry a given number of ampères with a given per cent. loss; the abscissas represent various voltages from 110 to 1,500 volts, and the ordinates the corresponding constants,

which, when multiplied by the mean distance, or one-half the total length of the circuit in feet, and the number of ampères to be transmitted, and divided by the per cent. loss, give the size of the wire in circular mils. That is:

$$\text{Circular mils} = \frac{\text{ampères} \times \text{mean distance (feet)} \times C}{\text{per cent. loss.}}$$



What will be the cost of a copper conductor to carry a current of 1,250 volts from a dynamo to a 100 H. P. motor 5,000 ft. distant, assuming the loss of power in the line at 20%, and the cost of copper 20 cts. per lb.?

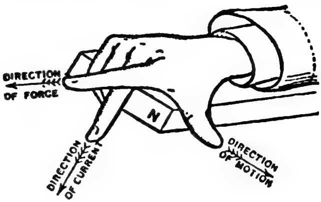
Ans.—As there is a loss of 20 per cent. in the line the voltage at the motor will be 1,000. Assuming the efficiency of the motor to be 90%, it must be supplied with 111 H. P., or 82,800 watts, which at 1,000 volts gives 82·8 ampères.

Referring to the curve, we find the constant for 1,250 volts is 1·83, and the

$$\text{cir. mils} = \frac{82{\cdot}8 \times 5{,}000 \times 1{\cdot}83}{20} = 37{,}875.$$

Multiplying 37,875 (the cir. mils) by 10,000 (the length of the circuit in feet), by ·0000006044, gives the price of the copper at 20 cents per pound, equal to $228.92.

Direction of Currents, etc.—If any circuit is being moved in a magnetic field, and it is required to know the direction in which electricity is flowing in any portion of the circuit which is cutting lines of force, proceed as follows:—Hold the first and middle finger and thumb of the *right* hand in a position at right angles to each other, so as to represent (as shown by the figure) the co-ordinate axes. Let the direction of the Forefinger represent the direction of the magnetic lines of Force. Let the direction of the thumb represent the direction in which the wire or armature is Moving, then the direction of the *middle* finger represents the direction of the Induced current in the wire.



The rule is easily applied to all parts of the armature of dynamo machines, for the direction of the magnetic field can always be ascertained by a pocket compass, and the forefinger being held parallel to the needle, with the finger pointing in the same way as the N, or marked end of the needle, while the thumb forms a tangent to the circle representing the revolving armature.

If we use the *left* hand in the same manner, the thumb indicates the direction of motion of a *motor* armature, due to a current flowing in the direction indicated by the middle finger. —*J. A. Fleming, D. Sc.*

If a compass needle be held *underneath* a wire in which a current is flowing, and the Forefinger of the *left hand* be placed *above* the wire parallel to the needle of the compass and pointing in the same direction as its North pole, then the Middle finger, held as in the above figure, at right angles to the Forefinger, will indicate the direction of the current in the wire. —*A. Jamieson.*

VALUABLE RECIPES FOR ELECTRICAL WORK.

Insulating Varnishes.—*Red varnish* for wood, etc., sealing wax dissolved in alcohol, and painted on with a brush in successive thin layers, say four or five.

For Galvanometer Coils.—Gum copal dissolved in ether, painted over each layer of wire and dried on a stove.

Shellac Varnish (Harris).—Put 1 ounce of shellac into a wide-mouthed 8 ounce phial containing 5 ounces of rectified naphtha or wood spirit. Cork and stand in a warm place until the gum is dissolved. Shake frequently and filter, adding more naphtha to assist the filtering, and changing the filter from time to time.

For Silk.—Mix 6 ounces of boiled linseed oil and 2 ounces of rectified spirits of turpentine.

For large Coils.—Cotton covered wires are now steeped in melted paraffin to increase their insulation. Large electro-magnet coils have a double covering of cotton, and the outer layer is coated with a thick varnish of shellac dissolved in alcohol.

Insulating Paper.—Absorbent tissue paper is rendered insulating by steeping it in melted paraffin, and is used for the dielectric of large telegraph condensers and Muirhead's artificial cable. An insulating varnish for paper is made by mixing one part of Canada balsam and two parts of essence of turpentine. Digest in a bottle with a gentle heat, and filter before cooling.

Saturating Tapes (*Madsen*).—Stockholm pitch eight parts, wax two parts, tallow one part.

Insulating Wood.—Wood for battery jars, etc., is also rendered insulating by steeping it in, or brushing it with, melted paraffin.

For Galvanoplasty.—An oaken trough, close made, and will last from twelve to fifteen years if coated with

Burgundy pitch....	1,500	grammes.
Old G. P. in shreds....	250	"
Pounded pumice....	750	"

Melt the G. P., mix with the pumice, and add the pitch. Apply liquid to the trough in several coats. A hot iron passed over the surface smooths it, and assists adhesion. The box resists sulphate of copper baths, but not cyanides.—(*E. Berthould.*)

Insulating Cement.—For *experimental work* a useful cement is made by melting together resin, beeswax and gutta percha in varying proportions. Sealing wax is also useful, especially the best qualities.

Cement for Insulators.—Sulphur, lead, or plaster of Paris mixed with a little glue to prevent too rapid settling.

Muirhead's Cement.—Three lbs. Portland cement, three lbs. rough sand, four pounds smithy ashes, and four lbs. resin.

Black Cement.—One lb. smithy ashes, one lb. rough sand, two lbs. resin.

Siemen's Cement.—Twelve lbs. black iron rust or iron filings, 100 lbs. sulphur.

Glue Cement; resisting damp,—one glue, one black resin, four red ochre mixed with least quantity of water; or four glue, one boiled oil by weight, three oxide of iron.

Cement for Leather.—Sixteen gutta percha, four india rubber, two pitch, one shellac, all cut small, with two of linseed oil, melted together and well mixed.

Acid-proof Cement.—A cement, which may be useful to electricians, is made by dissolving caoutchouc by carefully heating it in twice its weight of linseed oil, and then adding twice its weight of pipe-clay. The product forms a very plastic acid-proof mass, which, when heated, becomes softer, but does not melt. It can be kept for a long time in a damp place without hardening. When it becomes hard, it can be softened again by oil of turpentine.

Heat and Acid proof Cement:—

Sulphur	100 parts.
Tallow	2 "
Resin	2 "

Melt these together to a ruddy syrup, add sifted ground glass to form a paste, and heat when used.

Cement for Glass and Metal.—Best and purest gum arabic is put into a small quantity of water and left till next day, when it is of the consistency of molasses. Calomel (mercurous chloride or subchloride of mercury) is then added to make a sticky mass, and well mixed on a glass plate with a spatula. No more is to be made than is required for immediate use. The cement hardens in a few hours, but it is better to leave it for a day or two.

A GLOSSARY OF MINING TERMS.

Adit.—A horizontal passage into a mine driven in on a bed or vein, with just sufficient slope to ensure drainage.

Adze.—A curved cutting instrument for dressing timber.

Aerometers.—The air pistons of a Struve ventilator.

Aerophore.—The name given to an apparatus which will enable a man to enter places in mines filled with explosive or other deadly gases, with safety.

After-damp.—The deadly gases resulting from an explosion of fire-damp. Chiefly composed of carbonic acid gas. CO_2 or carbon 27 per cent. and oxygen 73 per cent.

Air.—The current of atmospheric air circulating through and ventilating the workings of a mine. To ventilate any portion of the workings.

Air-course.—See *Air-way.*

Air-crossing.—A bridge which carries one air-course over another.

Air-end Way.—Roadways or levels driven in the coal seam parallel with a main level, chiefly for the purpose of ventilation or for the return air. They are connected with the main level by openings or thirls.

Air-gates.—Underground roadways used principally for ventilating purposes.

Air-head.—See *Air-way.*

Air-heading.—An Air-way.

Airless end.—The extremity of a stall in long wall workings in which there is no current of air, or circulation of ventilation, but which is kept pure by diffusion, and by the ingress and egress of cars, men, etc.

Air-level.—A level or air-way (return air-way) of former workings, made use of in subsequent deeper mining operations for ventilating purposes.

Air-pipe, or *Air-box.*—Pipe or boxes used for the conveyance of air for ventilation; also, iron pipe used for the conveyance of compressed air.

Air-shaft.—A shaft or pit used expressly for ventilation.

Air-sollar.—A brattice carried beneath the tram rails or road bed, in a heading or gangway.

Air-stack.—A ventilating chimney.

Air-way.—Any passage in a mine through which air for ventilating purposes is passed.

Alternating Motion.—Up and down, or backward and forward motion.

Analysis.—To determine the proportion of original elements in a substance.

Anemometer.—An instrument used for measuring the velocity of a ventilating current.

Anneal.—To toughen metals, glass, etc., by first heating and then cooling very slowly. This lessens the tensile strength.

Anthracite.—A variety of coal. (See "Classification of Coals," under Colliery Management.)

Anticlinal Axis.—The ridge of a saddle in a mineral vein, or the line along the summit of a vein, from which the vein dips in opposite directions.

Apex.—The landing point at the top of a slope or inclined plane, the knuckle; also, the top of an anticlinal.

Arching.—Brickwork or stonework forming the roof of any underground roadway.

Arenaceous.—Sandy; rocks are arenaceous when they contain a considerable percentage of sand.

Argillaceous.—Clayey; rocks are argillaceous when they contain a considerable percentage of clay, or have some of the characteristics of clay.

Ascensional Ventilation.—The arrangement of the ventilating currents in such a manner that the heated air shall continuously rise until reaching the bottom of the upcast shaft. Particularly applicable to steep seams.

Ashler.—A facing of cut stone applied to a backing of rubble or rough masonry or brickwork.

Assay.—The determination of the quality of any particular substance in a mineral.

Auger-stem.—The iron rod or bar to which the bit is attached in rope drilling.

Axis.—An imaginary line passing through a body which may be supposed to revolve around it.

Azimuth.—The azimuth of a body is that arc of the horizon that is included between the meridian circle at the given place and another great circle passing through the body.

Back.—A plane or cleavage in coal, etc., having frequently a smooth parting and some sooty coal included in it.—The inner end of a heading or gangway.—To throw back into the gob, or waste, the small slack, dirt, etc.—To roll large coals out of a waste for loading into cars.

Back-casing.—A wall or lining of dry bricks used in sinking through drift deposits, the permanent walling being built up within it. The use of timber cribs and planking serves the same purpose.

Backing-deals.—Deal boards or planking placed at the back of curbs for supporting the sides of a shaft liable to run.

Back-lash.—The return or counter blast; recoil or backward suction of the air-current produced after an explosion of fire-damp.

Back-stay.—A wrought-iron forked bar attached to the back of cars, when ascending an inclined plane, which throws them off the rails if the rope or coupling breaks.

Baff-ends.—Long wooden edges for adjusting linings in sinking shafts, during the operation of fixing the lining.

Balance.—The counterpoise or weights attached to the drum of a winding engine, to assist the engine in lifting the load out of a shaft bottom, and in helping it to slacken speed when the cage reaches the surface. It consists often of a bunch of heavy chains suspended in a shallow shaft, the chains resting on the shaft bottom as unwound off the balance drum attached to the main shaft of the engine.

Balance-bob.—A large beam or lever attached to the main rods of a Cornish pumping engine, carrying on its outer end a counterpoise.

Balance-pit.—A pit or shaft in which a balance rises and falls.

Balk.—A more or less sudden thinning out of a seam of coal.—A bar of timber supporting the roof of a mine, or for carrying any heavy load.

Band.—A seam or thin stratum of stone or other refuse in a seam of coal.

Bank.—The top of the shaft, or out of the shaft.—The surface around the mouth of a shaft.—To manipulate coals, etc., on the bank.—The whole, or sometimes only one side or one end of a working place underground.—A large heap or stack of mineral on the surface.

Bank-head.—The upper end of an inclined plane next to the engine or drum made nearly level.

Banksman.—The man in attendance at the top of the shaft, superintending the work of banking.

Bar.—A length of timber placed horizontally for supporting the roof. In some cases bars of wrought-iron, about 3″ × 1″ × 5′, are used.

Barney.—A small car used on inclined planes and slopes to push the mine car up the slope.

Barney-pit.—A pit at the bottom of a slope or plane into which the barney runs to allow the mine car to pass over it.

Barren Ground.—Strata unproductive of seams of coal, etc., of a workable thickness.

Baring.—See *Stripping*.

Barrier Pillar.—A solid block or rib of coal, etc., left unworked between two collieries or mines for security against accidents arising from influx of water.

Barrier System.—The most modern and approved method of working a colliery by pillar and stall, where solid ribs or barriers of coal are left in between a set or series of working places.

Basin.—A coal field having some resemblance in form to a basin.—The synclinal axis of a seam of coal.

Batter.—The sloping backward of a face of masonry.

Battery.—A structure built to keep coal from sliding down a chute.

Bay.—An open space for waste between two packs in a long-wall working. See *Board*.

Bearing.—The course by a compass.—The span or length in the clear, between the points of support, of a beam, etc.—The points of support of a beam, shaft, axle, etc.

Bearing Door.—A door placed for the purpose of directing and regulating the amount of ventilation passing through an entire district of a mine.

Bearing in.—The depth or distance under of the undercut or holing.

Bearing-up Pulley.—A pulley wheel fixed in a frame and arranged to tighten up or take up the slack rope in endless rope haulage.

Bed.—The level surface of rock upon which a curb or crib is laid.—A stratum of coal, ironstone, clay, etc.

Bed-plate.—A large plate of iron used as a foundation for an engine to rest on.

Bench.—A natural terrace marking the outcrop of any stratum.—A stratum of coal forming a portion of the vein.

Benching.—To break up with wedges the bottom coals when the holing is done in the middle of the seam.

Bench Working.—The system of working one or more seams or beds of mineral by open working or stripping, in stages or steps.

Bevel gear.—Cog wheels, with teeth so formed that the wheels can work into each other at an angle.

Billy Playfair.—A mechanical contrivance for weighing coal, consisting of an iron trough with a sort of hopper bottom, into which all the small coal passing through the screen is conducted and weighed off and emptied from time to time.

Binder.—Indurated argillaceous shale, or clay, very commonly forming the roof of a coal seam, and frequently containing clay ironstone.

Bit.—A piece of steel placed in the cutting edge of a drill.

Blackband.—Carbonaceous ironstone in beds, mingled with coaly matter sufficient for its own calcination.

Black-damp.—Carbonic acid gas, much the same as after-damp. It will not support combustion or life.

Blast.—The sudden rush of fire and gas and dust of an explosion through the workings and roadways of a mine.—To cut or bring down coal, rocks, etc., by the explosion of gunpowder, dynamite, etc.

Block Coal.—Coal in large lumps.

Blossom.—The decomposed outcrop of a coal bed or mineral deposit.

Blow.—To blast with gunpowder, etc.—A dam or stopping is said to blow when gas escapes through it.

Blower.—A sudden emission or outburst of fire-damp in a mine.—An emission of fire-damp from the coal similar to that from an ordinary gas burner.

Blown-out Shot.—A shot that has blown out the tamping, but not broken the coal or rock.

Blue Cap.—The blue halo of ignited gas (fire-damp and air) on the top of the flame in a safety lamp, in an explosive mixture.

Board.—A wide heading, usually from 3 to 5 yards.

Board and Pillar.—A system of working coal, where the first stage of excavation is accomplished with the roof sustained by coal. Often called Breast and Pillar.

Bob.—An oscillating bell crank or lever, through which the motion of an engine is transmitted to the pump rods in an engine or pumping-pit. There are ⊥ bobs, L bobs and V bobs.

Bone.—Slaty coal, or carbonaceous shale found in coal seams.

Bonnet.—The overhead cover of a cage.—A cover for the top of a safety lamp.

Bore-hole.—A hole made with a drill, auger or other tools, either in coal rock or other material.

Bottom Pillars.—Large pillars left around the bottom of a shaft.

Bowk.—An iron barrel or tub used for hoisting rock and other debris when sinking a shaft.

Brattice.—A division or partition in a shaft, slope, heading, gangway or other underground working place for providing ventilation.

Brattice Cloth.—A heavy cloth or canvas, often covered with some water-proofing material, used in the construction of doors and brattices instead of plank.

Breaker.—The building or buildings in which anthracite coal is crushed and assorted into sizes, and cleaned for market.

Breast.—A stall, board or room in which coal is mined.

Breast and Pillar.—A system of working coal by boards or rooms with pillars of coal between them.

Bridge.—A platform on wheels, running upon rails for covering the mouth of a shaft or slope.

Bridle Chains.—Short chains by which a cage, car or gunboat is attached to a winding rope.

Briquettes.—Fuel made of slack or culm, and pressed into brick form.

Broken Coal.—Anthracite coal that will pass through a mesh or bars 3 1-4″ to 4 1-2″ and over a mesh 2 3-8″ to 2 7-8″.

Brush.—To mix air with the gas in a mine working by swinging a jacket, etc., which creates a current.

Bucket.—The top valve or clack of a pump.

Buck Wheat.—Anthracite coal that will pass through a mesh 3-8″ to 5-8″ and over a mesh of 3-16″ to 3-8″.

Buggy.—A small mine car.

Bull Engine.—A single, direct acting pumping engine, the pump rods forming a continuation of the piston-rod.

Buntons.—Timbers placed horizontally across a shaft or slope to carry the cage guides, pump rods, column pipe, etc.; also, to strengthen the shaft timbering.

Butt Heading.—A heading driven square with the cleavage of a seam.
Cage.—A platform on which mine cars are raised to the surface. (See *Slope Cage.*)
Cage Guides.—Vertical rods of pine, or of iron or steel, or wire rope fixed in a shaft, between which cages run, and whereby they are prevented from striking one another, or against any portion of the shaft.
Cannel Coal.—See "Classification of Coals" under "Colliery Management."
Cap.—(1) A piece of plank placed on top of a prop. (See also *Collar.*)
(2) The pale bluish elongation of the flame of a lamp caused by the presence of gas.
Car.—Any car used for the conveyance of coal along the gangways or haulage roads of a mine.
Carbon.—A combustible elementary substance forming the largest component part of coal.
Carbonaceous.—Coaly, containing carbon or coal.
Carboniferous.—Containing or carrying coal, thus: Carboniferous rocks, the carboniferous formation.
Carriage.—See *Cage* and *Slope Cage.*
Cartridge.—Paper or water-proof cylindrical cases filled with gunpowder, forming the charge for blasting.
Catches.—(1) Iron levers or props at the top and bottom of a shaft.
(2) Stops fitted on a cage to prevent cars from running off.
Casing.—Tubing inserted in a bore hole to keep out water or to protect the sides from collapsing.
Cave, Cave-in.—A caving in of the surface over mine workings.
CH_4.—The chemical symbol for fire-damp.
Chain-brow Way.—An underground inclined plane worked upon the endless chain system of haulage.
Chain-pillar.—A pillar left to protect the gangway and air course, and running parallel to these passages.
Chain Road.—An underground wagon way worked on the endless chain system of haulage.
Chamber.—See *Breast.*
Charge.—The amount of powder or other explosive used in one blast or shot.
Check-Battery.—A battery to close the lower part of a chute, acting as a check to the flow of coal and as an air stopping.
Check-weighman.—A man appointed and paid by the miners to weigh the coals on reaching the surface.
Chestnut Coal.—Anthracite coal that will pass through a mesh 1 in. to 1¼ in. square and over a mesh ¾ in. square.
Chock.—A square pillar constructed of short rectangular blocks of hard wood, for supporting the roof.
Choke-damp.—See *Black-damp.*
Chute (also spelled *Shute*).—A narrow inclined passage in a mine, down which coal is either pushed or slides by gravity.
Clack.—The lower valve of lifting or forcing pumps.
Clack-piece.—The casting forming the valve chamber.
Clanny.—A type of safety lamp, invented by Dr. Clanny.
Cleat.—(1) Natural jointing of coal seams, with generally a north and south direction, irrespective of dip or strike.
(2) A small piece of wood nailed to two planks to keep them together, or nailed to any structure to make a support for something else.
Clinometer.—An instrument used to measure the angle of dip.
Clod.—A layer of soft shale or slate, forming a very bad roof to a coal bed.
Coal Road.—An underground roadway or heading driven in coal.
Coal Smut.—See *Blossom.*
Collar.—(1) A horizontal timber supported on two *Legs*, the three constituting a set of timber.
(2) A flat ring surrounding anything closely.
Colliery.—The whole plant, including the mine and all adjuncts.
Colliery Warnings (British).—Telegraphic messages sent from signal service stations to the principal colliery centers to warn managers of mines, when sudden falls of the barometer occur.
Column.—The length of pipe conveying the drainage water from the mine to the surface.
Conical Drum.—The rope roll or drum of a winding engine, constructed in the form of two truncated cones placed back to back, the outer ends being usually the smallest in diameter. They equalize the load on the engines at all points.
Cores.—Cylindrical shaped pieces of rock produced by the diamond drill system of boring.
Cornish Pumps.—A single acting pump, in which the motion is transmitted through a walking beam; in other respects similar to a *Bull Pump.*
Counter-chute.—A chute down which coals are dumped to a lower level or gangway.
Counter-gangway.—A level or gangway driven at a higher level than the main one.
Course.—The direction in regard to the points of compass.
Creep.—(1) The gradual upheaval of the floor of a mine, due to the weight of the overlying strata and a tender floor.
(2) The gradual subsidence of the strata over a worked-out area of coal.
Crib.—A structure composed of horizontal frames of timber laid upon one another, or a frame work built like a log cabin.
Crop.—See *Outcrop.*

Crop-fall.—A caving-in of the surface at or near the outcrop of a bed of coal.
Cross-cut.—(1) A tunnel driven through or across the measures from one seam to another.
(2) A small passageway driven at right angles to the main gangway to connect it with a parallel gangway or air course.
Cross-hole.—See *Cross-cut* (2).
Crush.—See *Squeeze.*
Culm.—Anthracite coal dirt.
Danger Board.—See *Fire Board.*
Davy.—A safety lamp invented by Sir Humphrey Davy.
Day-shift.—The relay of men working in the daytime.
Dead-work.—Work which at the time it is done and of itself produces little or no profit.
Deep (British).—"To the deep," toward the lower portion of a mine, hence, the lower workings.
Detaching Hook.—A self-acting mechanical contrivance for setting free a winding rope from a cage when the latter is raised beyond a certain point in the head-gear; the rope being released the cage remains suspended in the frame.
Dial (British).—An instrument similar to a surveyor's compass, with vernier attached.
Dip.—(1) To slope downwards from the surface.
(2) The inclination of the strata, or a coal seam.
Dirt Fault.—A confusion in a seam of coal. The top and bottom of the seam being well defined, but the body of the vein being soft and dirty.
Ditch.—(1) The drainage gutter in a mine.
(2) A drainage gutter on the surface.
Dividing Slate.—A stratum of slate separating two benches of coal.
Dog.—An iron bar, spiked at the ends, with which timbers are held together or steadied.
Doors.—Wooden doors fixed in underground roads to serve as stoppings.
Double Shift.—A colliery is said to be working double shift when there are two sets of men at work, one set relieving the other.
Double Timber.—Two props with a bar placed across the tops of them, to support the roof and sides.
Down-cast.—The opening through which the fresh air is drawn or forced into the mine; the intake.
Drag.—The frictional resistance offered to a current of air in a mine.
Drift.—An opening or gangway driven from the surface into the coal above water level.
Drum.—The cylinder or pulley on which the winding ropes are coiled or wound.
Drum Rings.—Cast iron rings with projections, to which are bolted the laggings forming the surface for the ropes to lap on.
Dumb Drift.—A short tunnel or passage connecting the main return airways of a mine with the bottom of an upcast shaft, in order to prevent the return air from passing through or over the ventilating furnace.
Dumper.—A car so constructed that the body may be revolved to dump the material in front or on either side of the track.
Edge Coals (British).—Highly inclined seams of coal, or those having a dip greater than 30°.
Egg Coal.—Anthracite coal that will pass through a mesh or bars 2 3-8 in. to 2 7-8 in., and over a mesh or bars 1 3-4 in. to 2 1-4 in.
Empties.—Empty mine cars.
Entry.—A main haulage road or gangway.
Engine Plane.—Any underground way, either level or dipping, along which the cars are moved by engine power.
Endless Chain.—A system of haulage, in which the power is transmitted by the moving of an endless chain.
Endless Rope.—A system of haulage same as Endless Chain, except that a wire rope is used instead of chain.
End or End-on.—Working a seam of coals at right angles to the cleat, or natural planes of cleavage.
Face.—The place at which the coal is actually being worked away either in a breast or heading.
Face-on.—The reverse of end-on, or working a mine parallel to the cleat or face.
Fall.—(1) A mass of roof or side which has fallen in any part of a mine.
(2) To blast or wedge down coal.
Fan.—A centrifugal mechanical ventilator.
Fan Drift.—A short tunnel leading from near the top of the upcast shaft to the fan casing, along which the whole of the return air is drawn by the fan.
Fat Coals.—Those containing volatile oily matters.
Fault.—A fracture or disturbance of the strata breaking the continuity of the seam.
Feed.—Forward motion imparted to the cutters or drills of rock drilling or coal cutting machinery, either hand or automatic.
Feeder.—A small blower of gas.
Fiery.—Containing explosive gas.
Fire.—(1) A miner's term for fire-damp.
(2) To blast with gunpowder or other explosive.
(3) A word shouted by miners to warn one another when a shot is fired.
Fire-board.—A piece of board with the word *fire* painted upon it and suspended to a prop, etc., in the workings, to caution men not to take a naked light beyond it, or to pass it without the consent of the foreman or his assistants.

Fire Bosses.—Underground officials who examine the mine for gas, and inspect every safety lamp taken into the mine.
Fire Clay.—Any clay that will withstand a great heat without vitrifying.
Fire-damp.—The explosive gas of coal mines.—Light carburetted hydrogen.—The chemical formula is CH_4.
Fire-man.—See *Fire Boss.*
Flat.—A district or set of workings separated by faults, old workings or barriers of solid coal.
Floor.—(1) The stratum of rock upon which a seam of coal immediately lies.
(2) That part of a mine upon which you walk or the road bed is laid.
Fore-poling.—Driving poles over the timbers so that their ends project beyond the last set of timber, so as to protect the miner from roof falls; used also in quicksand or other loose material.
Furnace.—A large coal fire at or near the bottom of an upcast shaft for producing a current of air for ventilating the mine.
Gangway.—The main haulage road or level.
Gas.—See *Fire-damp*. Any mixture of this gas and air in an explosive condition is called gas.
Gasket.—A band or ring of any material put between the flanges of pipes before bolting to make them water or steam tight.
Gate.—An underground road connecting a stall or breast with a main road.
Gauge-door.—A wooden door fixed in an airway for regulating the supply of ventilation necessary for a certain district or number of men, etc.
Geordie. A safety lamp invented by George Stephenson.
Gin or *Horse Gin.*—A drum and framework carrying small pulleys, etc., by which the minerals and dirt are raised from a shallow pit.
Goaf or *Goave.*—That part of a mine from which the coal has been worked away, and the space more or less filled up.
Gob.—(1) Another word for *Goaf.*
(2) To leave behind in the mine coal and other minerals which are not marketable.
(3) To stow or pack with rubbish any useless underground roadway.
Gob-fire.—Spontaneous combustion underground.
Gob Road.—A gallery or way in a mine carried through the goaf.
Ground Rent.—Rent paid for surface occupied by the plant, etc., of a colliery.
Guides.—See *Cage Guides.*
Gunboat.—A self-dumping car, holding from 5 to 8 tons of coal, used upon inclined planes or slopes. They are filled by emptying the mine cars into them at the foot of the slope.
Gutter.—The drainage ditch in a mine.
Half-course.—(1) At an angle of 45° from general or previous course.
(2) Half on the level and half on the dip.
Hanger-on.—The man who runs the loaded cars on to the cages and gives the signal to hoist.
Hanging Wall.—In metalliferous mining the stratum lying on the upper side of a bed or vein.
Hat Rollers.—Cast iron or steel rollers shaped like a hat, revolving upon a vertical pin, for guiding incline hauling ropes around curves.
Haulage Clip.—Levers, jaws, wedges, etc., by which cars, singly or in trains, are connected to the hauling ropes.
Head-gear.—The pulley frame erected over a shaft.
Heading.—(1) A continuous passage for air, or for use as a manway.
(2) A connecting passage between two rooms, breasts or other working places.
(3) A gangway or entry.
Heep-stead (British).—The entire surface plant of a colliery.
Hog-back.—Sharply rising of the floor of a coal seam.
Hole.—(1) To undercut a seam of coal by hand or machine.
(2) A borehole.
(3) To make a communication from one part of a mine to another.
Holing.—(1) The portion of the seam removed from beneath the coal before it is broken down.
(2) A short passage connecting two roads.
Hood.—See *Bonnet.*
Horn Coal.—Coal worked partly *end-on* and partly *face-on.*
Horses or *Horsebacks.*—Natural channels cut, or washed away by water, in a coal seam, and filled up with shale and sandstone. Sometimes a bank or ridge of foreign matter in a coal seam.
Hutch (British).—A mine car.
Hydro-carbons.—Compounds of hydrogen and carbon.
Inbye (British).—Going into the interior of the mine, away from the shafts or other openings.
Incline.—Short for inclined plane. Any underground roadway driven at an angle to the horizon.
Indicator.—(1) A mechanical contrivance attached to winding, hauling or other machinery which shows the position of the cages in the shaft or the cars upon an incline during its journey or run.
(2) An apparatus for showing the presence of fire-damp in mines; the temperature of goaves; the speed of a ventilator, etc. And also for calculating the power of an engine.

Inset.—The entrance to a mine at the bottom or part way down a shaft where the cages are loaded.
Inspector.—A government official whose duties are to enforce the laws regulating the working of mines.
Intake.—(1) The passage through which the fresh air is drawn or forced in a mine, commencing at the bottom of the downcast.
(2) The fresh air passing into a colliery.
Inversion.—An axis at which point the vein instead of dipping or rising in the opposite direction turns and dips or rises parallel to the part already worked.
Jack.—A lantern shaped case made of tin, in which safety lamps are carried in strong currents of ventilation.
Jack Lamp.—A Davy lamp, with the addition of a glass cylinder outside the gauze.
Jig.—(1) A self-acting incline.
(2) A machine for separating ores or minerals from worthless rock by means of their difference in specific gravity. Also called jigger or washer.
Jigger.—(1) A kind of coupling hook for connecting cars upon an incline.
(2) An allowance of liquor sometimes issued to workingmen. (Almost obsolete.)
Joints.—Natural divisions, cracks or partings in strata.
Jugulars.—Timbers set obliquely against the rib in a breast to form a triangular passage to be used as a manway, airway or chute.
Jump.—An upthrow or a downthrow fault.
Jumper.—A hand drill used in boring holes in rock for blasting.
Keeps or *Keps.*—Wings, catches or rests to hold the cage at rest when it reaches any landing.
Kibble.—See *Bowk*; but often made with a bow or handle, and carrying over a ton of debris.
Kind Chaudron.--A system of sinking shafts through water bearing strata.
Kitty.—A squib made of a straw tube filled with powder.
Koepe System.—A system of hoisting without using drums, the rope being endless and passing over pulleys instead of around a drum.
Lagging.—(1) Small round timbers, slabs or plank driven in behind the legs and over the colla to prevent pieces of the sides or roof from falling through.
(2) Long pieces of timber closely fitted together and fastened to the drum rings to form a surface for the rope to wind on.
Lamp-men.—Cleaners, repairers and those having charge of the safety lamps at a colliery.
Lamp Stations.—Certain fixed stations in a mine at which safety lamps are allowed to be opened and relighted by men appointed for that purpose, or beyond which, on no pretense, is a naked light allowed to be taken.
Landing.—(1) A level stage for loading or unloading coals upon.
(2) The top or bottom of a slope, shaft or inclined plane.
Land-sale.—The sale of coal loaded into carts or wagons for local consumption.
Land-sale Collieries.—Those selling the entire product for local consumption, and shipping none by rail or water.
Lap.—One coil of rope upon a drum or pulley.
Large.—The largest lumps of coal sent to the surface, or all coal which is hand-picked or does not pass over screens; also, the largest coals which do pass over screens.
Larry.—(1) A car to which an endless rope is attached, fixed at the inside end of the road, forming part of an appliance for taking up slack rope.
(2) See *Barney*.
(3) A car with a hopper bottom and adjustable chutes for feeding coke ovens.
Latches.—A synonym of switch. Applied to the split rail and hinged switches.
Leader.—A seam of coal too small to be worked profitably, but often being a guide to larger seams lying in known proximity to it.
Leg.—A wooden prop supporting one end of a collar.
Level.—A road or gangway running parallel or nearly so with the strike of the seam.
Lift.—(1) The vertical height traveled by a cage in a shaft.
(2) The distance between the first level and the surface or between two levels, in seams with a heavy dip, measured on the dip of the seam.
Lifting Guards.—Fencing placed around the mouth of a shaft, which is lifted out of the way by the ascending cage.
Lignite.—A coal of a woody character, containing about 66 per cent. of carbon.
Lime Cartridge.—A charge or measured quantity of compressed dry caustic lime, made up into a cartridge and used instead of gunpowder for breaking down coal. Water is applied to the cartridge, and the expansion breaks down the coal without producing a flame.
Lime Coal.—Small coal suitable for lime burning.
Lines.—Plumb lines, not less than two in number, hung from hooks driven in wooden plugs. A line drawn through the centres of the two strings or wires, as the case may be, represents the bearing or course to be driven on.
Loader.—One who fills the mine cars at the working places.
Long Pillar Work.—A system of working coal seams in three separate operations. First, large pillars are left. Secondly, a number of parallel headings are driven through the block; and, lastly, the ribs or narrow pillars are worked away in both directions.
Long Ton.—2,240 pounds.

Long Wall.—A system of working a seam of coal in which the whole of the seam is taken out and no pillars, excepting the shaft pillars and sometimes the main road pillars, are left.
Loose End.—A portion of the seam worked on two sides.
Main Road.—The principal underground passage or gangway along which the produce of the mine is conveyed to the shaft or slope bottom.
Main Rope.—A system of underground haulage, in which the weight of the empty cars is sufficient to draw the rope in after them.
Manager.—An official who has the daily control and supervision of a mine, both under and above ground.
Man Hole.—(1) A refuge hole constructed in the side of a gangway, tunnel or slope.
(2) A hole in cylindrical boilers through which a man can get into the boiler to examine or repair it.
Manway.—A small passage used as a traveling way for the miner, and also often used as an airway or chute, or both.
Marsh Gas.—In mining language synonomous with *Fire-damp*.
Measures.—Strata.
Miner.—A collier or man who mines coal. Also applied to workers in metal mines.
Monitor.—See *Gunboat.*
Monkey Drift.—A small drift driven in for prospecting purposes.
Monkey Gangway.—A small airway parallel with the main gangway.
Monkey Rolls.—The smaller rolls in an anthracite breaker.
Motive Column.—The length of column of air in the downcast shaft which would be equal in weight to the difference in weight of the air in downcast and upcast shafts. The power obtained by furnace ventilation is measured by the difference of the weight of the air in the two shafts.
Mouth.—The top of a shaft or slope, or the entrance to a drift or tunnel.
Muessler Lamp.—A type of safety lamp invented and exclusively used in the collieries of Belgium. Also, endorsed by the Royal Commission on Accidents in Mines of Great Britain.
Naked Light.—A candle or any form of lamp which is not a safety lamp.
Narrow Work.—Headings, chutes, cross-cuts, gangways, etc., or *Deadwork.*
Natural Ventilation.—Ventilating a mine without either furnace or other artificial means; the heat imparted to the air by the strata, men, animals and lights in the mine, causing it to flow in one direction or towards the deepest shaft.
Needle.—A sharp-pointed metal rod, with which a small hole is made through the stemming to the cartridge in blasting operations.
Night Shift.—The set of men who work during the night.
Nogs.—Logs of wood piled one on another to support the roof.
Nuts.—Small lumps of coal which will pass through a screen, or bars the space between which vary in width from 1-2 inch to 2 1-2 inches.
Odd Work.—Work other than that done by contract, such as repairing roads, constructing stoppings, dams, etc.
Off-take—The raised portion of an upcast shaft above the surface, for carrying off smoke and steam, etc., produced by the furnaces and engines underground.
Oil-shale.—Shale containing such a proportion of hydrocarbons as to be capable of yielding mineral oil on slow distillation.
Outburst.—A *Blower*. A sudden exudation of large quantities of fire-damp.
Outbye.—In the direction of the shaft or slope bottom.
Outcrop.—That portion of a vein or bed, or any stratum appearing at the surface, or occurring immediately below the soil or diluvial drift.
Outlet.—A passage furnishing an outlet for air, for the miners, for water, or for the mineral mined.
Overcast.—A passage through which the ventilating current is conveyed over a gangway or airway.
Pack.—A rough wall or block of coal or stone built up to support the roof.
Packing.—The material placed in stuffing boxes, etc., to prevent leaks.
Pack Wall.—A wall of stone or rubbish built on either side of a mine road to carry the roof and keep the sides up.
Panel.—A large rectangular block or pillar of coal, measuring say 130 by 100 yards.
Panel Working.—A system of working coal seams, in which the colliery is divided up into large squares or panels, isolated or surrounded by solid ribs of coal, in each of which a separate set of breasts and pillars is worked, and the ventilation is kept distinct, that is, every panel has its own intake and return, the air of one not passing into the adjoining one, but being carried direct to the upcast shaft.
Parting.—Any thin interstratified bed of earthy material.
Pass-by.—A siding in which cars pass one another underground. A Turnout.
Pea Coal.—A small size of anthracite coal.
Pick.—(1) A tool for cutting and holing coal.
(2) To dress with a pick the sides or face of an excavation.
Picker.—A small tool used to pull up the wick of a miner's lamp.
Picking Chute.—A chute in an anthracite breaker, along which boys are stationed to pick the slate from coal.
Picking Table.—A flat or slightly inclined platform on which anthracite coal is run to be picked free from slate.
Piling.—Long pieces of timber driven into soft ground for the purpose of securing a solid base on which to build any superstructure.
Pillar.—A solid block of coal, etc., varying in area from a few square yards to several acres.
Pillar and Stall.—See *Breast and Pillar.*

Pillar Roads.—Working roads or inclines in pillars having a range of long-wall faces on either side.
Pinch.—To thin out.
Piped Air.—Air carried into the working places by pipes or brattices.
Pit.—(1) A shaft.
(2) The underground portion of a colliery, including all workings.
Pit Bottom.—The portion of a mine immediately around the bottom of a shaft or slope.
Pitch.—Dip or rise of a seam.
Pit Coal.—Generally signifies the bituminous varieties of coal.
Pit-head Man.—The man who has charge at the top of a shaft or slope.
Pitman.—A miner; also, one who looks after the pumps, etc.
Pit Prop.—A piece of timber used as a temporary support for the roof.
Pit Rails.—Mine rails for underground roads.
Pit Room.—The extent of the underground workings in use or available for use.
Pit-top.—The mouth of a shaft or slope.
Plan.—(1) The system on which a colliery is worked as "long-wall," "pillar and breast," etc.
(2) A map or plan of the colliery, showing outside improvements and underground workings.
Plane.—A main road, either level or inclined, along which coal is conveyed by engine-power or gravity.
Plank Dam.—A water-tight stopping fixed in a heading constructed of timber placed across the passage, one upon another, sideways and tightly wedged.
Plank Tubbing.—Shaft lining of planks, driven down vertically behind wooden cribs all round the shaft, all joints being tightly wedged to keep back the water.
Plant.—The shafts or slope, tunnels, engine-houses, railways, machinery, workshops, etc., of a colliery or other mine.
Plenum.—A mode of ventilating a mine or a heading by forcing fresh air into it.
Plunger.—The solid ram of a force pump working in the Plunger Case.
Plunger Case.—The pump cylinder or barrel in which the plunger works.
Pocket.—(1) A thickening out of a seam of coal or other mineral over a small area.
(2) A hopper shaped receptacle from which coal or ore is loaded into cars or boats.
Post and Stall.—A system of working coal much the same as Pillar and Stall.
Pot Hole.—A circular hole in the rock caused by the action of stones whirled around by the water when the strata was covered by water. They are generally filled with sand and diluvial drift.
Pricker.—(1) A thin brass rod for making a hole in the stemming when blasting, for the insertion of a fuse.
(2) A piece of bent wire by which the size of the flame in a safety lamp is regulated, without removing the top of the lamp.
Prop.—A wooden or cast-iron temporary support for the roof.
Propping.—The timbering of a mine.
Prospecting.—Examining a tract of country in search of minerals.
Protector Lamp.—A safety lamp, the flame of which it is impossible to expose to the outward atmosphere, as the action of opening the lamp extinguishes the light.
Prove.—(1) To ascertain by boring, driving, etc., the position and character of a coal seam, a fault, etc.
(2) To examine a mine in search of fire-damp, etc., known as proving the pit.
Proving-hole.—(1) A bore-hole driven for prospecting purposes.
(2) A small heading driven in to find a bed or vein lost by a dislocation of the strata, or to prove the quality of the mineral in advance of the other workings.
Pudding Rock.—Conglomerate.
Pulley.—(1) The wheel over which a winding rope passes at the top of the head gear.
(2) Small wooden cylinders, over which a winding rope is carried on the floor or sides of a plane.
Pump Rods.—Heavy timbers, by which the motion of the engine is transmitted to the pump. In Cornish and Bull pumps, the weight of these rods makes the effective (pumping) stroke, the engine merely lifting the rods on the up-stroke.
Pump Slope.—A slope used for pumping machinery.
Pump Station.—An enlargement made in the shaft, slope or gangway, to receive the pump.
Punch and Thirl.—A kind of pillar and stall system of working.
Quicksand.—Soft watery strata, easily moved or readily yielding to pressure.
Rails.—The iron or steel portion of the tramway or railroad.
Rance.—A pillar of coal.
Rapper.—A lever with a hammer attached at one end, which signals by striking a plate of metal, when the signalling wire, to which it is attached, is pulled.
Red Ash Coal.—Coal that produces a reddish ash, when burnt.
Refuge Hole.—A place formed in the side of an underground plane in which men can take refuge when trips are passing or a shot is fired.
Regulator.—A door in a mine, the opening or shutting of which regulates the supply of ventilation to a district of the mine.
Repairman.—A workman whose duty it is to repair tracks, doors, brattices, or to reset timbers, etc., under the direction of the foreman.
Rests, Keeps, Wings.—Supports on which a cage rests when the loaded car is being taken off and the empty one put on.

Return.—The air course along which the vitiated air of a mine is returned or conducted back to the upcast shaft.
Return Air.—The air which has been passed through the workings.
Rib.—The side of a pillar.
Rib and Pillar.—A system of working similar to Pillar and Stall.
Ride.—To be conveyed on a cage or mine car.
Rider.—(1) A guide frame for steadying a sinking bucket.
(2) Boys who ride on trips on mechanical haulage roads.
(3) A thin seam of coal overlying a thicker one.
Ring.—(1) A complete circle of tubbing plates placed round a circular shaft.
(2) Troughs placed in shafts to catch the falling water, and so arranged as to convey it to a determined point.
Rise.—The inclination of the strata, when looking up the pitch.
Rise Workings.—Underground workings carried on to the rise or high side of the shaft.
Road.—(1) Any underground passageway, or gallery.
(2) The iron rails, etc., of underground roads.
Rob.—To cut away or reduce the size of pillars of coal.
Rock Drill.—A rock-boring machine worked by hand, compressed air, steam or electrical power.
Rock Fault.—A replacement of a coal seam over greater or less area, by some other rock, usually sandstone.
Roll.—An inequality in the roof or floor of a mine.
Roller.—A small steel, iron or wooden wheel or cylinder upon which the hauling rope is carried just above the floor.
Rolls.—Cast iron cylinders fitted with steel teeth, used in anthracite breakers to break coal into various sizes.
Roof.—The top of any subterraneous passage.
Room.—Synonymous with Breast.
Room and Rance.—A system of working coal similar to Pillar and Stall.
Rope Roll.—The drum of a winding engine.
Round Coal.—Coal in large lumps, either hand picked, or after passing over screens, to take out the small.
Royalty.—The price paid per ton to the owner of mineral land by the lessor.
Rubbing Surface.—The total area of a given length of airway. That is, the area of top, bottom and sides added together, or the perimeter multiplied by the length.
Run.—(1) The sliding and crushing of pillars of coal.
(2) The length of a lease or tract on the strike of the seam.
Run Coal.—Soft bituminous coal.
Runner.—A man or boy whose duty it is to run mine cars by gravity from working places to the gangway.
Saddle.—An anticlinal, a hog-back.
Saddleback.—A depression in the strata. See *Roll.*
Safety Cage.—A cage fitted with an apparatus for arresting its motion in the shaft in case the rope breaks.
Safety Catches.—Appliances fitted to cages to make them *Safety Cages.*
Safety Door.—A strongly constructed door, hinged to the roof, and always kept open and hung near to the main door, for immediate use when main door is damaged by an explosion or otherwise.
Safety Lamp.—A miners' lamp, in which the flame is protected in such a manner that an explosive mixture of air and fire-damp can be detected by the mixture burning inside of the gauze This warns the miner to extinguish his light, as the mixture is dangerous.
Salting.—Sprinkling salt upon the floors of underground passages in very dry mines in order to lay the dust.
Scale.—(1) A small portion of the ventilative current in a mine passing through a certain sized aperture.
(2) The rate of wages to be paid, which varies under certain contingencies.
Scale Door.—See *Regulator.*
Scissors Fault.—A fault of dislocation, in which two beds are thrown so as to cross each other.
Scoop.—A large sized shovel with a scoop-shaped blade.
Scraper.—(1) A tool for cleaning the dust out of a bore hole.
(2) A mechanical contrivance used at collieries to scrape the culm or slack along a trough to the place of deposit.
Screen.—(1) A mechanical apparatus for separating small from large coals.
(2) A cloth brattice or curtain hung across a road in a mine to direct the ventilation.
Sea Coal.—That which is transported by sea.
Sealing.—Shutting off all air from a mine or part of a mine by stoppings.
Seam.—Synonymous with *Bed, Vein,* etc.
Second Outlet.—A passageway out of a mine for use in case of accident to the main outlet.
Second Working.—The operation of getting or working out the pillars formed by the first working.
Self-acting Plane.—An inclined plane upon which the weight or force of gravity acting upon the full cars is sufficient to overcome the resistance of the empties; in other words, the full car, running down, pulls the empty car up.
Separation Doors.—Doors fixed underground (generally two, sometimes three) between the intake and the return, near the shaft or slope bottom.

Separation Valve.—A massive cast iron plate suspended from the roof of a return airway, through which all the return air of a separate district flows, allowing the air to always flow past or underneath it; but in the event of an explosion of gas, the force of the blast closes it against its frame or seating, and prevents a communication with other districts. The blast being over, the weight of the valve allows it to return to its normal position.

Set.—(1) To fix in place a prop or sprag.
(2) Timbers fixed in a gangway, etc., as in *Double Timber*, which see.

Shaft.—A vertical pit or hole made through strata, through which the produce of the mine is brought to the surface, and through which the ventilation is passed either into or out of the mine.

Shaft Pillar.—Solid coal left unworked beneath colliery buildings and around the shaft, to support them against subsidence.

Shale.—Strictly speaking, all argillaceous strata that split up or peel off in thin laminæ.

Sheave.—A wheel with a grooved circumference, over which a rope is turned, either for the transmission of power or for winding or hauling.

Shearing.—Cutting a vertical groove in coal similar to an undercut.

Sheets.—Coarse cloth curtains or screens for directing the ventilative current underground.

Shift.—A certain number of hours of work; a certain proportion or change of workmen.

Shooting.—Blasting in a mine.

Shot.—(1) A blast.
(2) The firing of a blast.
(3) Injured by a blast.

Shot Hole.—The bore hole in which the explosive substance is placed for blasting.

Shot Lighter or *Shot Firer.*—A man specially appointed by the manager of the mine to fire off every shot in a certain district, after he has examined the immediate neighborhood of the shot and found it free from gas, and otherwise safe.

Show.—When the flame of a safety lamp becomes elongated or unsteady, owing to the presence of fire-damp in the air it is said to show.

Shutter.—A movable sliding door, having balance weights attached, fitted within the outer casing of a Guibal or other closed fan, for regulating the size of the opening from the fan, to suit the ventilation and economical working of the machine.

Side.—(1) The more or less vertical face or wall of coal or goaf forming one side of an underground working place.
(2) Rib.
(3) A district.

Side Chain.—A chain hooked on to the sides of cars running on an incline or along a gangway, to keep the cars together in case a coupling breaks.

Sight.—A bearing or angle taken with a compass or transit when making a survey.

Sing.—The noise made by a feeder of gas issuing from the coal.

Singing Lamp.—A safety lamp, which, when placed in an atmosphere of explosive gas, gives out a peculiar sound or note, the strength of the note varying in proportion to the percentage of fire-damp present.

Single Rope Haulage.—A system of underground haulage, in which a single rope is used, the empty trip running in by gravity.

Sink.—To excavate.—To bore or put down a bore hole.

Sinker.—A man who works at the bottom of a shaft in course of being sunk.

Siphon.—A simple, very effective and economical mode of conveying water in a mine over a hill. It takes the form of an iron pipe, bent like an inverted U; the vertical height between the water and top of hill must not exceed 28 or 30 feet, and the discharge end must be lower than the suction end.

Skids.—Slides upon which heavy bodies are slid from place to place.

Skip (English).—(1) A mine car.
(2) To remove or rob part of a pillar.

Slack.—Small coal which will pass through a screen. There is no standard size distinguishing coal from slack.

Slant.—An underground roadway, driven more or less on the rise or dip of the seam.

Slate-picker.—(1) A man or boy who picks the slate or bony coal from anthracite coal.
(2) A mechanical contrivance for separating slate from coal.

Sliding Scale.—A mode of regulating the wages paid workingmen, by taking as a basis for calculation the market price of coal, the wages rising and falling with the state of trade.

Slip.—(1) A fault.
(2) A smooth joint or crack in strata.

Slit.—A short heading put through to connect two other headings.

Slope.—The main engine plane or inclined roadway driven in the seam of coal worked from the outcrop, up which the whole of the produce of the mine is raised by the winding engine.

Small.—See *Slack*.

Smift.—A bit of touch-paper, touch-wood, etc., attached by a bit of clay or grease to the outside end of the train of gunpowder when blasting. Its object is to ignite the shot after giving the miner sufficient time to reach a place of safety.

Socket.—(1) The innermost end of a shot hole not blown away after firing.
(2) A wrought iron contrivance, by means of which a wire rope is securely attached to a chain or hook.

Sole.—A piece of timber set underneath a prop.

Sounding.—(1) Knocking on a roof to see whether it is sound or safe to work under.
(2) Rapping on a pillar so that a person on the other side of it may be signaled to or to enable him to estimate its width.

Spiders.—See *Drum Rings.*

Spiral Drum.—See *Conical Drum.*

Splint or *Splent.*—A laminated, coarse, inferior, dull looking, hard coal, producing much white ash; intermediate between cannel and bituminous coal.

Split.—(1) A division of the air current under ground.
(2) To divide the ventilative current.
(3) To divide a pillar by driving a passage through it.

Spout.—A short underground passage connecting a main road with an air course.

Sprag.—(1) A short wooden prop set in a slanting position for keeping up the coal during the operation of holing.
(2) A short round piece of hard wood, pointed at both ends, to act as a brake when placed between the spokes of mine car wheels.

Spring Latch.—A spring or automatic switch.

Spud.—A nail with a hole in the head driven into the mine timbers, or a wooden plug fitted into the roof to mark a surveying station.

Squeeze.—See *Creep.*

Squib.—A straw, rush, paper or quill tube filled with a priming of gunpowder, with a slow match on one end.

Stage.—A platform upon which mine cars stand.

Stage Pumping.—Draining a mine by means of two or more pumps placed at different levels, each of which raises the water to the next pump above or to the surface.

Stage Working.—A system of working minerals by removing the strata above the beds, after which the various beds are removed in steps or stages.

Stall.—A breast or chamber.

Stall Gate.—A road along which the mineral worked in a stall is conveyed to the main road.

Standing.—Not at work, not going forward, idle.

Standing Gas.—A body of fire-damp known to exist in a mine, though fenced off.

Staple.—A shallow pit within a mine.

Starter.—A man who ascends a chute to the battery and starts the coal to run.

Steam Coal.—A hard, free burning, non-caking coal.

Steam Jet.—A system of ventilating a mine by means of a number of jets of steam at high pressure kept constantly blowing off from a series of pipes in the bottom of the upcast shaft.

Steining.—The brick or stone lining of a shaft.

Stemmer.—A copper or wooden bar used for stemming.

Stemming.—(1) Fine shale or dirt put into a shot hole after the powder, and rammed hard.—Tamping.
(2) Ramming or beating the stemming solid.

Stint.—The amount of work to be done by a man in a specified time.

Stone Coal.—Anthracite in lumps.

Stonehead.—A heading or gangway driven in stone. A tunnel.

Stone Tubbing.—Water-tight stone walling of a shaft, jointed and fastened at the back with cement.

Stook.—A pillar of coal about four yards square, being the last portion of a full-sized pillar to be worked away in Board and Pillar workings.

Stook and Feather.—A wedge for breaking down coal, worked by hydraulic power, the pressure being applied at the extreme inner edge of the drilled hole.

Stoop.—A pillar of coal.

Stoop and Room.—A system of working coal very similar to Pillar and Stall.

Stopping.—An air-tight wall built across any passageway in a mine.

Stow.—To pack away rubbish into goaves or old workings.

Straight Ends and Walls.—A system of working coal somewhat similar to Board and Pillar. Straight Ends are headings from four feet six inches to six feet in width. Walls are pillars thirty feet wide.

Strett.—The system of getting coal by headings or narrow work. See *Board and Pillar.*

Strike.—The line at right angles to the dip; a level course.

Strike Joints.—Joints in strata parallel to the strike.

Strip.—To remove the overlying strata of a bed of mineral, and take it out by open work.

Struck.—Level full, as a struck bushel.

Struve Ventilator.—A pneumatic ventilating apparatus, consisting of two vessels like gas holders, which are moved up and down in water. By this means the air is sucked out of the mine as required.

Stump.—The block of solid coal at the entrance to a breast, having a narrow passage-way on either side.

Stythe.—Carbonic acid gas.

Sulphur.—An old term for fire-damp.

Sump or *Sumpt.*—A receptacle into which the drainage of a mine flows and from which it is pumped to the surface.

Swabstick.—A short wooden rod, bruised into a kind of stumpy brush at one end, for cleaning out a drilled hole.

Swamp.—A depression or natural hollow in a seam. A basin.

Sweet.—Free from deleterious gases.

Synclinal.—The point at which the rocks incline away from each other like the two legs of the letter V. A basin.

Synclinal Axis.—The line or course of a synclinal as determined by tracing a line through the lowest points along any stratum.
Tail Back.—When fire-damp ignites and the flame is elongated or creeps backwards against the current of air, it is said to tail back.
Tailing.—The blossom, the outcrop or smut.
Tail-pipe.—The suction of a pump.
Tail Rope.—(1) A round steel or iron wire rope, working in conjunction with and being an appendage to a main rope in the system of underground haulage, where the inclination of the gangways is only slight. The empty cars are drawn in by the tail rope, and the loaded out by the main rope.
(2) A wire rope attached to cages as a balance.
Tail Rope System of Haulage.—This is worked with a single road or line of rails, and generally applied under the following circumstances. When the average gradient of the road is not sufficient to cause the empty cars to draw a single rope in after it; when the gradient dipping out is not sufficient to establish a self-acting plane system; or when the gradient for the full cars is not sufficient to enable the trip to draw a single rope after it. The full trip is drawn out by the main rope, and the empty trip is drawn in by the tail rope, both ends of the trip being attached to a rope. The engine has two drums, one for each rope, one always running loose while the other is in gear.
Take the Air.—To measure the ventilating current.
Tally.—A mark or number placed by the miner on every car of coal sent out of his place, usually a tin ticket. By counting these, a tally is made of all the cars of coal he sends out.
Tamp.—To fill up a bore hole above the charge with some strongly resistant substance rammed hard upon the powder.
Tamping.—The stuff used to tamp with.—See *Stemming.*
Tap.—(1) To cut or bore into old workings for the purpose of liberating accumulations of gas or water.
(2) To win coal in a new district.
Teem, sometimes *Tem.*—To tip rubbish, etc., down a dump.
Teeming Trough.—A trough into which the water from a mine is pumped.
Telegraphs.—Chutes which convey coal from the screens to pockets.
Thill.—See *Floor.*
Thirl.—See *Cross Cut* (2).
Throw.—(1) A fault of dislocation.
(2) The vertical distance between the two fractured ends of a bed of coal, etc., at a fault.
Thrown.—Faulted, broken up by a fault.
Thrust.—Creep or Squeeze due to weight.
Timber.—(1) Props, bars, collars, legs, laggings, etc.
(2) To set or place timber in a mine.
Time.—Hours of work performed by daymen, laborers, etc.
Tin Can Safety Lamp.—A Davy lamp placed inside a tin can or cylinder, having a glass in front, air holes near the bottom and open topped, making the lamp safer in a rapid current of air.
Tip.—A dump.
Tipper or *Tippler.*—An apparatus for emptying cars of coal by turning them upside down, and then bringing them back to original position with a minimum of manual labor.
Tipple.—The chutes or pockets into which bituminous coal is dumped from mine cars, and from which, after being weighed, it is loaded into cars or boats for shipment.
Top.—See *Roof.*
Track.—Railways or Tramways.
Train Boy.—A boy who rides on the trip to attend to rope attachments, signal in case of derailment of cars, etc.
Tram.—A mine car.
Tram-road.—A mine track or railroad.
Tram-rope.—A hauling rope, to which the cars are attached by a clip or chain, either singly or in trips.
Trap.—(1) A steep heading along which men travel.
(2) A fault of dislocation.
Trap Door.—A small door, kept locked, fixed in a stopping, for giving access to firemen and certain others to the return airways, dams or other unused portions of the mine.
Trap Dyke.—A fault (not necessarily accompanied by displacement of strata) in which the spaces between the fractured edges of the beds are filled up by a thick wall of igneous rock.
Trapper.—A small boy employed underground to open and shut doors during the passage of trips.
Traveling Road.—An underground passage or way used expressly, though not always exclusively, for men to travel along to and from their working places.
Trip.—The number of mine cars in one train or set.
Trompe.—A water-blast apparatus for producing ventilation by the fall of water down a shaft.
Trough Fault.—A wedge shaped fault, or, more correctly, a mass of rock, coal, etc., let down in between two faults, which faults, however, are not necessarily of equal throw.

Trying the Lamp.—The examination of the flame of a safety lamp for the purpose of forming a judgment as to the quantity of fire-damp mixed with the air.
Tub.—A mine car.
Tubbing.—Cast iron, and sometimes timber lining or walling of a shaft, to keep back springs of water from flowing into a mine.
Tunnel.—A gangway driven through rock.
Turn.—(1) The hours during which coal, etc., is being raised from the mine.
(2) See *Shift.*
(3) To open headings or chutes.
Turn-out.—A siding or pass-by upon an underground railway.
Turn Pulley.—A sheave fixed at the inside end of an endless or tail-rope hauling plane, round which the rope returns.
Turntable.—A revolving platform on which cars or locomotives are turned round.
Undercast.—An aircourse carried under another.
Underclay.—A bed of fireclay or other less clayey stratum lying immediately beneath a seam of coal.
Undercut.—To remove a small portion of the bottom of the bed so that the mass can be wedged or blasted down.
Underviewer or *Underlooker.*—An inside foreman.
Upcast.—The shaft through which the return air ascends and is got rid of.
Upthrow.—A fault which appears as an upthrow.
Vacuum.—An unoccupied space from which the air has been removed without allowing other air to flow in.
Vein.—A seam of coal or other mineral.
Vent or *Vent Hole.*—A small passage made with a needle through the tamping, which is used for admitting a squib, to enable the charge to be lighted.
Ventilating Column.—See *Motive Column.*
Ventilating Pressure.—The power or force required to overcome the friction of the air in mines.
Ventilation.—The atmospheric air circulating in a mine.
Ventilator.—A mechanical apparatus for producing a current of air underground.
Viewer.—The general manager or mining engineer of one or more collieries, who has control of the whole of the underground works, and also generally of those upon the surface.
Volatile.—Capable of wasting away or evaporating.
Wagon.—A mine car.
Wall.—(1) The face of a long wall working or breast.
(2) A rib of solid coal between two breasts.
Walling.—See *Steining.*
Walling Cribs.—Oak cribs or curbs upon which walling is built.
Walling Stage.—A movable wooden scaffold suspended from a crab on the surface, upon which the workmen stand when walling or lining a shaft.
Warners.—Apparatus consisting of a variety of delicately constructed machines, actuated by chemical, physical, electrical and mechanical properties, for indicating the presence of small quantities of fire-damp in the mines. At present most of these ingenious contrivances are more suited to the laboratory than for practical application underground.
Warning Lamp.—A safety lamp fitted with certain delicate apparatus for indicating very small proportions of fire-damp in the atmosphere of a mine. As small a quantity as 0·03 per cent. can be by this means determined.
Wash.—Drift, clay, stones, etc., overlying the strata.
Wash Fault.—A portion of a seam of coal replaced by shale or sandstone.
Washing Apparatus or Machine.—(1) Machinery and appliances erected on the surface at a colliery, generally in connection with coke-ovens, for extracting, by washing with water, the impurities mixed with the coal dust or small slack. The principle upon which the process is performed is that of gravitation or precipitation.
(2) Machinery for removing impurities from small sizes of anthracite coal on the same principle.
Waste.—(1) See *Goaf.*
(2) Very small coal or slack.
Water Blast.—The sudden escape of pent-up air in rise workings under considerable pressure from a head of water which has accumulated in the lower workings.
Water Cartridge.—A waterproof cartridge surrounded by an outer case. The space between being filled with water, which is employed to destroy the flame produced when the shot is fired, thereby lessening the chance of an explosion should gas be present in the place.
Water Gauge.—An instrument for measuring the drag or friction of air in mines.
Water Level.—An underground passage or heading driven very nearly dead level or on the strike for the purpose of draining off the water.
Weather.—To crumble by exposure to the atmosphere.
Wedging Crib.—A curb or crib of cast iron upon which tubbing is built up and wedged tightly to, in order to stop back all water.
Wedging Down.—Breaking down the coal at the face with hammers and wedges instead of by blasting.
Weize.—A band or ring of spun yarn, rope, rubber, lead, etc., put in between the flanges of pipes before bolting them together, in order to make a water-tight joint.

Whim.—A winding drum worked by a horse.
Whin.—A hard compact rock.
Whin Dyke.—A fault or fissure filled with whin and the debris of othe rocks, sometimes accompanied by a dislocation of the strata.
White Damp.—Carbonic oxide. A gas occasionally found in coal mines, generally a product of combustion. Although it will support combustion, and under certain conditions it is inflammable, it quickly destroys life.
Win.—To sink a shaft or slope, or drive a drift to a workable seam of mineral in such a manner as to permit its being successfully worked.
Winch.—A kind of windlass or crab for coiling ropes upon.
Wind Gauge.—An anemometer for testing the velocity of air in mines.
Winding.—The operation of raising, by means of a steam engine and ropes, the produce of a mine.
Winding Engines.—Hoisting engines.
Wind Method.—A system of separating coal into various sizes, and extracting the dirt from it, which in principle depends upon the specific gravity or size of the coal and the strength of the current of air.
Winning.—A sinking shaft, a new coal, ironstone, clay, shale or other mine of stratified mineral.
Won.—Proved, sunk to and tested.
Workable.—Any seam that can be profitably mined.
Worked Out.—When all available mineral has been extracted from a mine it is worked out.
Working Barrel.—The water cylinder of a pump.
Working Cost.—The total cost of producing the mineral.
Working Home.—Getting or working out a seam of coal, etc., from the boundary or far end of the mine toward the shaft bottom.
Working on Air.—A pump works on air when air is sucked up with the water.
Working Place.—The actual place in a mine at which the coal is being mined.
Working Out.—Working outwards or in the direction of the boundaries of the colliery.
Workings.—The openings of a colliery, including all roads, ways, levels, dips, airways, etc., etc.
Yard Work.—Synonymous with Yardage.
Yardage.—Price paid per yard for cutting coal.
Yield.—The proportion of a seam sent to market.
Zone.—In coal mining phraseology this word means a certain series of coal seams with their accompanying shales, etc., which contain, for example, much firedamp, called a *fiery zone*, or, if much water, a *watery zone*

LOGARITHMS OF NUMBERS.

HOW TO USE THEM.

Logarithms are numbers designed to diminish the labor of multiplication and division, by substituting in their stead addition and subtraction. The base of the system is 10, and, as a logarithm is the exponent of the power to which the base must be raised in order to be equal to a given number, all numbers are to be regarded as powers of 10; hence,

$10^0 = 1$ we have logarithm of $1 = 0$
$10^1 = 10$ we have logarithm of $10 = 1$
$10^2 = 100$ we have logarithm of $100 = 2$
$10^3 = 1{,}000$ we have logarithm of $1{,}000 = 3$
$10^4 = 10{,}000$ we have logarithm of $10{,}000 = 4$

Therefore, the logarithms of any number between 1 and 10 are less than unity, and are expressed as decimals. The logarithm of any number between 10 and 100 is more than 1 and less than 2, hence it is equal to one plus a decimal. Between 100 and 1,000 it is equal to 2 plus a decimal, etc. Hence the following rule:

The characteristic of a logarithm is always one less than the number of whole figures expressing that number.

The characteristic of the logarithm of 7 is 0; the characteristic of 17 is 1; the characteristic of 717 is 2, etc.

To find the logarithm of any number between 1 and 100, look on the first page of the table, along the column marked No., for the given number; opposite it will be found the logarithm with its characteristic.

To find the logarithm of any number consisting of three figures, proceed in the same manner and find the decimal in the first column to the right of the number, prefix to this the characteristic 2. Thus the logarithm of 327 is 2·514548. As the first two figures of the decimal are the same for several successive figures, they are only given where they change. Thus, the decimal part of the logarithm of 302 is ·480007. The first two figures remain the same up to 310, and are therefore to be supplied.

To find the logarithm of any number of four figures, look in the column headed No., for the first three figures, and then along the top of the page for the fourth figure. Down the column headed by the fourth figure, and opposite the first three, will be found the decimal part. To this prefix the characteristic, 3.

To find the logarithm of any number containing more than four figures, find the decimal part of the logarithm of the first four figures, then multiply the number in the column of differences by the remaining figures, and add to the decimal part as many figures of the result, counting from the left, as there were figures in the multiplier. Then prefix the characteristic according to the rules previously given.

Example.—What is the logarithm of 452789?

Decimal part of logarithm 4527 is	·655810
Difference is 96. $96 \times 89 =$	85+
Decimal part of logarithm of 452789 =	·655895+

Characteristic = 5; hence, logarithm is 5·655895.

To find the logarithm of a decimal fraction, proceed according to previous rules, except in regard to the characteristic. Where the number consists of a whole number and a decimal, the characteristic is one less than the *whole* number. Where it is a simple decimal, or when there are no ciphers between the decimal point and the first numerator, the characteristic is negative, and is expressed by 1, with a minus sign over it. Where there is one cipher between the decimal point and first numerator the characteristic is 2, with a minus sign over it. Where there are two ciphers the characteristic is 3, with a minus sign over it. Thus:

The logarithm of 67·7 is 1·831037
The logarithm of 6·77 is 0·831037
The logarithm of ·677 is $\bar{1}$·831037
The logarithm of ·0677 is $\bar{2}$·831037
The logarithm of ·00677 is $\bar{3}$·831037

The characteristic only is negative. The decimal part is positive.

To find the logarithm of a vulgar fraction, subtract the logarithm of the denominator from the logarithm of the numerator. The difference is the logarithm of the fraction.

To find the natural number corresponding to any logarithm, look in the column headed 0 for the first two figures of the decimal part, the other four figures are to be looked for in the same or in one of the nine following columns. If they are exactly found the number must be made to correspond with the characteristic by pointing off decimals or annexing ciphers.

If the decimal portion can not be found exactly, find the next lower logarithm, subtract it from the given logarithm, divide the difference by the number found in the difference column, and annex the quotient to the natural number found opposite the lower logarithm.

To multiply by the use of logarithms, add the logarithms of the factors together; the sum will be the logarithm of their product.

To divide by use of logarithms, subtract the logarithm of the divisor from the logarithm of the dividend; the difference will be the logarithm of the quotient.

To square a number by the use of logarithms, multiply the logarithm of the number by 2. The product will be the logarithm of the square of the number.

To cube a number, multiply the logarithm of the number by 3. The product will be the logarithm of the cube of the number.

To raise a number to any power, as 4th, 5th, 6th, or 7th, multiply the logarithm of the number by 4, 5, 6, or 7, and the results will be the logarithms of the 4th, 5th, 6th, or 7th powers respectively. Thus a number can readily be raised to any power required.

To extract the square, cube, fourth, fifth, or any root of a number, divide the logarithm of the number by the index of the root required, and the quotient will be the logarithm of the required root.

Thus, to find the square root of 625:

$$\text{Logarithm of } 625 = 2{\cdot}795880$$
$$2{\cdot}795880 \div 2 = 1{\cdot}397940$$
$$1{\cdot}397940 = \text{Logarithm of } 25$$

Therefore, the square root of 625 is 25.

To find the cube, fourth, or any root, proceed in the same way, using the index of the required root as a divisor.

TABLE OF LOGARITHMS OF NUMBERS, FROM 1 TO 10,000.

No.	Logarithm.	No.	Logarithm.	No.	Logarithm.	No.	Logarithm.	No.	Logarithm.
1	0·000000	21	1·322219	41	1·612784	61	1·785330	81	1·908485
2	0·301030	22	1·342423	42	1·623249	62	1·792392	82	1·913814
3	0·477121	23	1·361728	43	1·633468	63	1·799341	83	1·919078
4	0·602060	24	1·380211	44	1·643453	64	1·806180	84	1·924279
5	0·698970	25	1·397940	45	1·653213	65	1·812913	85	1·929419
6	0·778151	26	1·414973	46	1·662758	66	1·819544	86	1·934498
7	0·845098	27	1·431364	47	1·672098	67	1·826075	87	1·939519
8	0·903090	28	1·447158	48	1·681241	68	1·832509	88	1·944483
9	0·954243	29	1·462398	49	1·690196	69	1·838849	89	1·949390
10	1·000000	30	1·477121	50	1·698970	70	1·845098	90	1·954243
11	1·041393	31	1·491362	51	1·707570	71	1·851258	91	1·959041
12	1·079181	32	1·505150	52	1·716003	72	1·857332	92	1·963788
13	1·113943	33	1·518514	53	1·724276	73	1·863323	93	1·968483
14	1·146128	34	1·531479	54	1·732394	74	1·869232	94	1·973128
15	1·176091	35	1·544068	55	1·740363	75	1·875061	95	1·977724
16	1·204120	36	1·556303	56	1·748188	76	1·880814	96	1·982271
17	1·230449	37	1·568202	57	1·755875	77	1·886491	97	1·986772
18	1·255273	38	1·579784	58	1·763428	78	1·892095	98	1·991226
19	1·278754	39	1·591065	59	1·770852	79	1·897627	99	1·995635
20	1·301030	40	1·602060	60	1·778151	80	1·903090	100	2·000000

No.	0	1	2	3	4	5	6	7	8	9	Diff
100	000000	000434	000868	001301	001734	002166	002598	003029	003461	003891	432
1	4321	4751	5181	5609	6038	6466	6894	7321	7748	8174	428
2	8600	9026	9451	9876	010300	010724	011147	011570	011993	012415	424
3	012837	013259	013680	014100	4521	4940	5360	5779	6197	6616	420
4	7033	7451	7868	8284	8700	9116	9532	9947	020361	020775	416
5	021189	021603	022016	022428	022841	023252	023664	024075	4486	4896	412
6	5306	5715	6125	6533	6942	7350	7757	8164	8571	8978	408
7	9384	9789	030195	030600	031004	031408	031812	032216	032619	033021	404
8	033424	033826	4227	4628	5029	5430	5830	6230	6629	7028	400
9	7426	7825	8223	8620	9017	9414	9811	040207	040602	040998	397
110	041393	041787	042182	042576	042969	043362	043755	044148	044540	044932	393
1	5323	5714	6105	6495	6885	7275	7664	8053	8442	8830	390
2	9218	9606	9993	050380	050766	051153	051538	051924	052309	052694	386
3	053078	053463	053846	4230	4613	4996	5378	5760	6142	6524	383
4	6905	7286	7666	8046	8426	8805	9185	9563	9942	060320	379
5	060698	061075	061452	061829	062206	062582	062958	063333	063709	4083	376
6	4458	4832	5206	5580	5953	6326	6699	7071	7443	7815	373
7	8186	8557	8928	9298	9668	070038	070407	070776	071145	071514	370
8	071882	072250	072617	072985	073352	3718	4085	4451	4816	5182	366
9	5547	5912	6276	6640	7004	7368	7731	8094	8457	8819	363
120	079181	079543	079904	080266	080626	080987	081347	081707	082067	082426	360
1	082785	083144	083503	3861	4219	4576	4934	5291	5647	6004	357
2	6360	6716	7071	7426	7781	8136	8490	8845	9198	9552	355
3	9905	090258	090611	090963	091315	091667	092018	092370	092721	093071	352
4	093422	3772	4122	4471	4820	5169	5518	5866	6215	6562	349
5	6910	7257	7604	7951	8298	8644	8990	9335	9681	100026	346
6	100371	100715	101059	101403	101747	102091	102434	102777	103119	3462	343
7	3804	4146	4487	4828	5169	5510	5851	6191	6531	6871	341
8	7210	7549	7888	8227	8565	8903	9241	9579	9916	110253	338
9	110590	110926	111263	111599	111934	112270	112605	112940	113275	3609	335
130	113943	114277	114611	114944	115278	115611	115943	116276	116608	116940	333
1	7271	7603	7934	8265	8595	8926	9256	9586	9915	120245	330
2	120574	120903	121231	121560	121888	122216	122544	122871	123198	3525	328
3	3852	4178	4504	4830	5156	5481	5806	6131	6456	6781	325
4	7105	7429	7753	8076	8399	8722	9045	9368	9690	130012	323
5	130334	130655	130977	131298	131619	131939	132260	132580	132900	3219	321
6	3539	3858	4177	4496	4814	5133	5451	5769	6086	6403	318
7	6721	7037	7354	7671	7987	8303	8618	8934	9249	9564	316
8	9879	140194	140508	140822	141136	141450	141763	142076	142389	142702	314
9	143015	3327	3639	3951	4263	4574	4885	5196	5507	5818	311
140	146128	146438	146748	147058	147367	147676	147985	148294	148603	148911	309
1	9219	9527	9835	150142	150449	150756	151063	151370	151676	151982	307
2	152288	152594	152900	3205	3510	3815	4120	4424	4728	5032	305
3	5336	5640	5943	6246	6549	6852	7154	7457	7759	8061	303
4	8362	8664	8965	9266	9567	9868	160168	160469	160769	161068	301
5	161368	161667	161967	162266	162564	162863	3161	3460	3758	4055	299
6	4353	4650	4947	5244	5541	5838	6134	6430	6726	7022	297
7	7317	7613	7908	8203	8497	8792	9086	9380	9674	9968	295
8	170262	170555	170848	171141	171434	171726	172019	172311	172603	172895	293
9	3186	3478	3769	4060	4351	4641	4932	5222	5512	5802	291
150	176091	176381	176670	176959	177248	177536	177825	178113	178401	178689	289
1	8977	9264	9552	9839	180126	180413	180699	180986	181272	181558	287
2	181844	182129	182415	182700	2985	3270	3555	3839	4123	4407	285
3	4691	4975	5259	5542	5825	6108	6391	6674	6956	7239	283
4	7521	7803	8084	8366	8647	8928	9209	9490	9771	190051	281
5	190332	190612	190892	191171	191451	191730	192010	192289	192567	2846	279
6	3125	3403	3681	3959	4237	4514	4792	5069	5346	5623	278
7	5900	6176	6453	6729	7005	7281	7556	7832	8107	8382	276
8	8657	8932	9206	9481	9755	200029	200303	200577	200850	201124	274
9	201397	201670	201943	202216	202488	2761	3033	3305	3577	3848	272
No.	0	1	2	3	4	5	6	7	8	9	Diff

No.	0	1	2	3	4	5	6	7	8	9	Diff
160	204120	204391	204663	204934	205204	205475	205746	206016	206286	206556	271
1	6826	7096	7365	7634	7904	8173	8441	8710	8979	9247	269
2	9515	9783	210051	210319	210586	210853	211121	211388	211654	211921	267
3	212188	212454	2720	2986	3252	3518	3783	4049	4314	4579	266
4	4844	5109	5373	5638	5902	6166	6430	6694	6957	7221	264
5	7484	7747	8010	8273	8536	8798	9060	9323	9585	9846	262
6	220108	220370	220631	220892	221153	221414	221675	221936	222196	222456	261
7	2716	2976	3236	3496	3755	4015	4274	4533	4792	5051	259
8	5309	5568	5826	6084	6342	6600	6858	7115	7372	7630	258
9	7887	8144	8400	8657	8913	9170	9426	9682	9938	230193	256
170	230449	230704	230960	231215	231470	231724	231979	232234	232488	232742	255
1	2996	3250	3504	3757	4011	4264	4517	4770	5023	5276	253
2	5528	5781	6033	6285	6537	6789	7041	7292	7544	7795	252
3	8046	8297	8548	8799	9049	9299	9550	9800	240050	240300	250
4	240549	240799	241048	241297	241546	241795	242044	242293	2541	2790	249
5	3038	3286	3534	3782	4030	4277	4525	4772	5019	5266	248
6	5513	5759	6006	6252	6499	6745	6991	7237	7482	7728	246
7	7973	8219	8464	8709	8954	9198	9443	9687	9932	250176	245
8	250420	250664	250908	251151	251395	251638	251881	252125	252368	2610	243
9	2853	3096	3338	3580	3822	4064	4306	4548	4790	5031	242
180	255273	255514	255755	255996	256237	256477	256718	256958	257198	257439	241
1	7679	7918	8158	8398	8637	8877	9116	9355	9594	9833	239
2	260071	260310	260548	260787	261025	261263	261501	261739	261976	262214	238
3	2451	2688	2925	3162	3399	3636	3873	4109	4346	4582	237
4	4818	5054	5290	5525	5761	5996	6232	6467	6702	6937	235
5	7172	7406	7641	7875	8110	8344	8578	8812	9046	9279	234
6	9513	9746	9980	270213	270446	270679	270912	271144	271377	271609	233
7	271842	272074	272306	2538	2770	3001	3233	3464	3696	3927	232
8	4158	4389	4620	4850	5081	5311	5542	5772	6002	6232	230
9	6462	6692	6921	7151	7380	7609	7838	8067	8296	8525	229
190	278754	278982	279211	279439	279667	279895	280123	280351	280578	280806	228
1	281033	281261	281488	281715	281942	282169	2396	2622	2849	3075	227
2	3301	3527	3753	3979	4205	4431	4656	4882	5107	5332	226
3	5557	5782	6007	6232	6456	6681	6905	7130	7354	7578	225
4	7802	8026	8249	8473	8696	8920	9143	9366	9589	9812	223
5	290035	290257	290480	290702	290925	291147	291369	291591	291813	292034	222
6	2256	2478	2699	2920	3141	3363	3584	3804	4025	4246	221
7	4466	4687	4907	5127	5347	5567	5787	6007	6226	6446	220
8	6665	6884	7104	7323	7542	7761	7979	8198	8416	8635	219
9	8853	9071	9289	9507	9725	9943	300161	300378	300595	300813	218
200	301030	301247	301464	301681	301898	302114	302331	302547	302764	302980	217
1	3196	3412	3628	3844	4059	4275	4491	4706	4921	5136	216
2	5351	5566	5781	5996	6211	6425	6639	6854	7068	7282	215
3	7496	7710	7924	8137	8351	8564	8778	8991	9204	9417	213
4	9630	9843	310056	310268	310481	310693	310906	311118	311330	311542	212
5	311754	311966	2177	2389	2600	2812	3023	3234	3445	3656	211
6	3867	4078	4289	4499	4710	4920	5130	5340	5551	5760	210
7	5970	6180	6390	6599	6809	7018	7227	7436	7646	7854	209
8	8063	8272	8481	8689	8898	9106	9314	9522	9730	9938	208
9	320146	320354	320562	320769	320977	321184	321391	321598	321805	322012	207
210	322219	322426	322633	322839	323046	323252	323458	323665	323871	324077	206
1	4282	4488	4694	4899	5105	5310	5516	5721	5926	6131	205
2	6336	6541	6745	6950	7155	7359	7563	7767	7972	8176	204
3	8380	8583	8787	8991	9194	9398	9601	9805	330008	330211	203
4	330414	330617	330819	331022	331225	331427	331630	331832	2034	2236	202
5	2438	2640	2842	3044	3246	3447	3649	3850	4051	4253	202
6	4454	4655	4856	5057	5257	5458	5658	5859	6059	6260	201
7	6460	6660	6860	7060	7260	7459	7659	7858	8058	8257	200
8	8456	8656	8855	9054	9253	9451	9650	9849	340047	340246	199
9	340444	340642	340841	341039	341237	341435	341632	341830	2028	2225	198
No.	0	1	2	3	4	5	6	7	8	9	Diff

No.	0	1	2	3	4	5	6	7	8	9	Diff
220	342423	342620	342817	343014	343212	343409	343606	343802	343999	344196	197
1	4392	4589	4785	4981	5178	5374	5570	5766	5962	6157	196
2	6353	6549	6744	6939	7135	7330	7525	7720	7915	8110	195
3	8305	8500	8694	8889	9083	9278	9472	9666	9860	350054	194
4	350248	350442	350636	350829	351023	351216	351410	351603	351796	1989	193
5	2183	2375	2568	2761	2954	3147	3339	3532	3724	3916	193
6	4108	4301	4493	4685	4876	5068	5260	5452	5643	5834	192
7	6026	6217	6408	6599	6790	6981	7172	7363	7554	7744	191
8	7935	8125	8316	8506	8696	8886	9076	9266	9456	9646	190
9	9835	360025	360215	360404	360593	360783	360972	361161	361350	361539	189
230	361728	361917	362105	362294	362482	362671	362859	363048	363236	363424	188
1	3612	3800	3988	4176	4363	4551	4739	4926	5113	5301	188
2	5488	5675	5862	6049	6236	6423	6610	6796	6983	7169	187
3	7356	7542	7729	7915	8101	8287	8473	8659	8845	9030	186
4	9216	9401	9587	9772	9958	370143	370328	370513	370698	370883	185
5	371068	371253	371437	371622	371806	1991	2175	2360	2544	2728	184
6	2912	3096	3280	3464	3647	3831	4015	4198	4382	4565	184
7	4748	4932	5115	5298	5481	5664	5846	6029	6212	6394	183
8	6577	6759	6942	7124	7306	7488	7670	7852	8034	8216	182
9	8398	8580	8761	8943	9124	9306	9487	9668	9849	380030	181
240	380211	380392	380573	380754	380934	381115	381296	381476	381656	381837	181
1	2017	2197	2377	2557	2737	2917	3097	3277	3456	3636	180
2	3815	3995	4174	4353	4533	4712	4891	5070	5249	5428	179
3	5606	5785	5964	6142	6321	6499	6677	6856	7034	7212	178
4	7390	7568	7746	7923	8101	8279	8456	8634	8811	8989	178
5	9166	9343	9520	9698	9875	390051	390228	390405	390582	390759	177
6	390935	391112	391288	391464	391641	1817	1993	2169	2345	2521	176
7	2697	2873	3048	3224	3400	3575	3751	3926	4101	4277	176
8	4452	4627	4802	4977	5152	5326	5501	5676	5850	6025	175
9	6199	6374	6548	6722	6896	7071	7245	7419	7592	7766	174
250	397940	398114	398287	398461	398634	398808	398981	399154	399328	399501	173
1	9674	9847	400020	400192	400365	400538	400711	400883	401056	401228	173
2	401401	401573	1745	1917	2089	2261	2433	2605	2777	2949	172
3	3121	3292	3464	3635	3807	3978	4149	4320	4492	4663	171
4	4834	5005	5176	5346	5517	5688	5858	6029	6199	6370	171
5	6540	6710	6881	7051	7221	7391	7561	7731	7901	8070	170
6	8240	8410	8579	8749	8918	9087	9257	9426	9595	9764	169
7	9933	410102	410271	410440	410609	410777	410946	411114	411283	411451	169
8	411620	1788	1956	2124	2293	2461	2629	2796	2964	3132	168
9	3300	3467	3635	3803	3970	4137	4305	4472	4639	4806	167
260	414973	415140	415307	415474	415641	415808	415974	416141	416308	416474	167
1	6641	6807	6973	7139	7306	7472	7638	7804	7970	8135	166
2	8301	8467	8633	8798	8964	9129	9295	9460	9625	9791	165
3	9956	420121	420286	420451	420616	420781	420945	421110	421275	421439	165
4	421604	1768	1933	2097	2261	2426	2590	2754	2918	3082	164
5	3246	3410	3574	3737	3901	4065	4228	4392	4555	4718	164
6	4882	5045	5208	5371	5534	5697	5860	6023	6186	6349	163
7	6511	6674	6836	6999	7161	7324	7486	7648	7811	7973	162
8	8135	8297	8459	8621	8783	8944	9106	9268	9429	9591	162
9	9752	9914	430075	430236	430398	430559	430720	430881	431042	431203	161
270	431364	431525	431685	431846	432007	432167	432328	432488	432649	432809	161
1	2969	3130	3290	3450	3610	3770	3930	4090	4249	4409	160
2	4569	4729	4888	5048	5207	5367	5526	5685	5844	6004	159
3	6163	6322	6481	6640	6799	6957	7116	7275	7433	7592	159
4	7751	7909	8067	8226	8384	8542	8701	8859	9017	9175	158
5	9333	9491	9648	9806	9964	440122	440279	440437	440594	440752	158
6	440909	441066	441224	441381	441538	1695	1852	2009	2166	2323	157
7	2480	2637	2793	2950	3106	3263	[illegible]	[illegible]	3732	3889	[illegible]
8	4045	4201	4357	4513	4669	4825	[illegible]	[illegible]	5293	5449	[illegible]
9	5604	5760	5915	6071	6226	6382	[illegible]	[illegible]	6848	[illegible]	[illegible]
No.	0	1	2	3	4	5	[illegible]	[illegible]	8	9	

No.	0	1	2	3	4	5	6	7	8	9	Diff
280	447158	447313	447468	447623	447778	447933	448088	448242	448397	448552	155
1	8706	8861	9015	9170	9324	9478	9633	9787	9941	450095	154
2	450249	450403	450557	450711	450865	451018	451172	451326	451479	1633	154
3	1786	1940	2093	2247	2400	2553	2706	2859	3012	3165	153
4	3318	3471	3624	3777	3930	4082	4235	4387	4540	4692	153
5	4845	4997	5150	5302	5454	5606	5758	5910	6062	6214	152
6	6366	6518	6670	6821	6973	7125	7276	7428	7579	7731	152
7	7882	8033	8184	8336	8487	8638	8789	8940	9091	9242	151
8	9392	9543	9694	9845	9995	460146	460296	460447	460597	460748	151
9	460898	461048	461198	461348	461499	1649	1799	1948	2098	2248	150
290	462398	462548	462697	462847	462997	463146	463296	463445	463594	463744	150
1	3893	4042	4191	4340	4490	4639	4788	4936	5085	5234	149
2	5383	5532	5680	5829	5977	6126	6274	6423	6571	6719	149
3	6868	7016	7164	7312	7460	7608	7756	7904	8052	8200	148
4	8347	8495	8643	8790	8938	9085	9233	9380	9527	9675	148
5	9822	9969	470116	470263	470410	470557	470704	470851	470998	471145	147
6	471292	471438	1585	1732	1878	2025	2171	2318	2464	2610	146
7	2756	2903	3049	3195	3341	3487	3633	3779	3925	4071	146
8	4216	4362	4508	4653	4799	4944	5090	5235	5381	5526	146
9	5671	5816	5962	6107	6252	6397	6542	6687	6832	6976	145
300	477121	477266	477411	477555	477700	477844	477989	478133	478278	478422	145
1	8566	8711	8855	8999	9143	9287	9431	9575	9719	9863	144
2	480007	480151	480294	480438	480582	480725	480869	481012	481156	481299	144
3	1443	1586	1729	1872	2016	2159	2302	2445	2588	2731	143
4	2874	3016	3159	3302	3445	3587	3730	3872	4015	4157	143
5	4300	4442	4585	4727	4869	5011	5153	5295	5437	5579	142
6	5721	5863	6005	6147	6289	6430	6572	6714	6855	6997	142
7	7138	7280	7421	7563	7704	7845	7986	8127	8269	8410	141
8	8551	8692	8833	8974	9114	9255	9396	9537	9677	9818	141
9	9958	490099	490239	490380	490520	490661	490801	490941	491081	491222	140
310	491362	491502	491642	491782	491922	492062	492201	492341	492481	492621	140
1	2760	2900	3040	3179	3319	3458	3597	3737	3876	4015	139
2	4155	4294	4433	4572	4711	4850	4989	5128	5267	5406	139
3	5544	5683	5822	5960	6099	6238	6376	6515	6653	6791	139
4	6930	7068	7206	7344	7483	7621	7759	7897	8035	8173	138
5	8311	8448	8586	8724	8862	8999	9137	9275	9412	9550	138
6	9687	9824	9962	500099	500236	500374	500511	500648	500785	500922	137
7	501059	501196	501333	1470	1607	1744	1880	2017	2154	2291	137
8	2427	2564	2700	2837	2973	3109	3246	3382	3518	3655	136
9	3791	3927	4063	4199	4335	4471	4607	4743	4878	5014	136
320	505150	505286	505421	505557	505693	505828	505964	506099	506234	506370	136
1	6505	6640	6776	6911	7046	7181	7316	7451	7586	7721	135
2	7856	7991	8126	8260	8395	8530	8664	8799	8934	9068	135
3	9203	9337	9471	9606	9740	9874	510009	510143	510277	510411	134
4	510545	510679	510813	510947	511081	511215	1349	1482	1616	1750	134
5	1883	2017	2151	2284	2418	2551	2684	2818	2951	3084	133
6	3218	3351	3484	3617	3750	3883	4016	4149	4282	4415	133
7	4548	4681	4813	4946	5079	5211	5344	5476	5609	5741	133
8	5874	6006	6139	6271	6403	6535	6668	6800	6932	7064	132
9	7196	7328	7460	7592	7724	7855	7987	8119	8251	8382	132
330	518514	518646	518777	518909	519040	519171	519303	519434	519566	519697	131
1	9828	9959	520090	520221	520353	520484	520615	520745	520876	521007	131
2	521138	521269	1400	1530	1661	1792	1922	2053	2183	2314	131
3	2444	2575	2705	2835	2966	3096	3226	3356	3486	3616	130
4	3746	3876	4006	4136	4266	4396	4526	4656	4785	4915	130
5	5045	5174	5304	5434	5563	5693	5822	5951	6081	6210	129
6	6339	6469	6598	6727	6856	6985	7114	7243	7372	7501	129
7	7630	7759	7888	8016	8145	8274	8402	8531	8660	8788	129
8	8917	9045	9174	9302	9430	9559	9687	9815	9943	530072	128
9	530200	530328	530456	530584	530712	530840	530968	531096	531223	1351	128
No.	0	1	2	3	4	5	6	7	8	9	Diff

No.	0	1	2	3	4	5	6	7	8	9	Diff
340	531479	531607	531734	531862	531990	532117	532245	532372	532500	532627	128
1	2754	2882	3009	3136	3264	3391	3518	3645	3772	3899	127
2	4026	4153	4280	4407	4534	4661	4787	4914	5041	5167	127
3	5294	5421	5547	5674	5800	5927	6053	6180	6306	6432	126
4	6558	6685	6811	6937	7063	7189	7315	7441	7567	7693	126
5	7819	7945	8071	8197	8322	8448	8574	8699	8825	8951	126
6	9076	9202	9327	9452	9578	9703	9829	9954	540079	540204	125
7	540329	540455	540580	540705	540830	540955	541080	541205	1330	1454	125
8	1579	1704	1829	1953	2078	2203	2327	2452	2576	2701	125
9	2825	2950	3074	3199	3323	3447	3571	3696	3820	3944	124
350	544068	544192	544316	544440	544564	544688	544812	544936	545060	545183	124
1	5307	5431	5555	5678	5802	5925	6049	6172	6296	6419	124
2	6543	6666	6789	6913	7036	7159	7282	7405	7529	7652	123
3	7775	7898	8021	8144	8267	8389	8512	8635	8758	8881	123
4	9003	9126	9249	9371	9494	9616	9739	9861	9984	550106	123
5	550228	550351	550473	550595	550717	550840	550962	551084	551206	1328	122
6	1450	1572	1694	1816	1938	2060	2181	2303	2425	2547	122
7	2668	2790	2911	3033	3155	3276	3398	3519	3640	3762	121
8	3883	4004	4126	4247	4368	4489	4610	4731	4852	4973	121
9	5094	5215	5336	5457	5578	5699	5820	5940	6061	6182	121
360	556303	556423	556544	556664	556785	556905	557026	557146	557267	557387	120
1	7507	7627	7748	7868	7988	8108	8228	8349	8469	8589	120
2	8709	8829	8948	9068	9188	9308	9428	9548	9667	9787	120
3	9907	560026	560146	560265	560385	560504	560624	560743	560863	560982	119
4	561101	1221	1340	1459	1578	1698	1817	1936	2055	2174	119
5	2293	2412	2531	2650	2769	2887	3006	3125	3244	3362	119
6	3481	3600	3718	3837	3955	4074	4192	4311	4429	4548	119
7	4666	4784	4903	5021	5139	5257	5376	5494	5612	5730	118
8	5848	5966	6084	6202	6320	6437	6555	6673	6791	6909	118
9	7026	7144	7262	7379	7497	7614	7732	7849	7967	8084	118
370	568202	568319	568436	568554	568671	568788	568905	569023	569140	569257	117
1	9374	9491	9608	9725	9842	9959	570076	570193	570309	570426	117
2	570543	570660	570776	570893	571010	571126	1243	1359	1476	1592	117
3	1709	1825	1942	2058	2174	2291	2407	2523	2639	2755	116
4	2872	2988	3104	3220	3336	3452	3568	3684	3800	3915	116
5	4031	4147	4263	4379	4494	4610	4726	4841	4957	5072	116
6	5188	5303	5419	5534	5650	5765	5880	5996	6111	6226	115
7	6341	6457	6572	6687	6802	6917	7032	7147	7262	7377	115
8	7492	7607	7722	7836	7951	8066	8181	8295	8410	8525	115
9	8639	8754	8868	8983	9097	9212	9326	9441	9555	9669	114
380	579784	579898	580012	580126	580241	580355	580469	580583	580697	580811	114
1	580925	581039	1153	1267	1381	1495	1608	1722	1836	1950	114
2	2063	2177	2291	2404	2518	2631	2745	2858	2972	3085	114
3	3199	3312	3426	3539	3652	3765	3879	3992	4105	4218	113
4	4331	4444	4557	4670	4783	4896	5009	5122	5235	5348	113
5	5461	5574	5686	5799	5912	6024	6137	6250	6362	6475	113
6	6587	6700	6812	6925	7037	7149	7262	7374	7486	7599	112
7	7711	7823	7935	8047	8160	8272	8384	8496	8608	8720	112
8	8832	8944	9056	9167	9279	9391	9503	9615	9726	9838	112
9	9950	590061	590173	590284	590396	590507	590619	590730	590842	590953	112
390	591065	591176	591287	591399	591510	591621	591732	591843	591955	592066	111
1	2177	2288	2399	2510	2621	2732	2843	2954	3064	3175	111
2	3286	3397	3508	3618	3729	3840	3950	4061	4171	4282	111
3	4393	4503	4614	4724	4834	4945	5055	5165	5276	5386	110
4	5496	5606	5717	5827	5937	6047	6157	6267	6377	6487	110
5	6597	6707	6817	6927	7037	7146	7256	7366	7476	7586	110
6	7695	7805	7914	8024	8134	8243	8353	8462	8572	8681	110
7	8791	8900	9009	9119	9228	9337	9446	9556	9665	9774	[illegible]
8	9883	9992	600101	600210	600319	600428	600537	600646	600755	[illegible]	[illegible]
9	600973	601082	1191	1299	1408	1517	1625	1734	1843	[illegible]	[illegible]
No.	0	1	2	3	4	5	6	7	8	[illegible]	[illegible]

No.	0	1	2	3	4	5	6	7	8	9	Diff
400	602060	602169	602277	602386	602494	602603	602711	602819	602928	603036	108
1	3144	3253	3361	3469	3577	3686	3794	3902	4010	4118	108
2	4226	4334	4442	4550	4658	4766	4874	4982	5089	5197	108
3	5305	5413	5521	5628	5736	5844	5951	6059	6166	6274	108
4	6381	6489	6596	6704	6811	6919	7026	7133	7241	7348	107
5	7455	7562	7669	7777	7884	7991	8098	8205	8312	8419	107
6	8526	8633	8740	8847	8954	9061	9167	9274	9381	9488	107
7	9594	9701	9808	9914	610021	610128	610234	610341	610447	610554	107
8	610660	610767	610873	610979	1086	1192	1298	1405	1511	1617	106
9	1723	1829	1936	2042	2148	2254	2360	2466	2572	2678	106
410	612784	612890	612996	613102	613207	613313	613419	613525	613630	613736	106
1	3842	3947	4053	4159	4264	4370	4475	4581	4686	4792	106
2	4897	5003	5108	5213	5319	5424	5529	5634	5740	5845	105
3	5950	6055	6160	6265	6370	6476	6581	6686	6790	6895	105
4	7000	7105	7210	7315	7420	7525	7629	7734	7839	7943	105
5	8048	8153	8257	8362	8466	8571	8676	8780	8884	8989	105
6	9093	9198	9302	9406	9511	9615	9719	9824	9928	620032	104
7	620136	620240	620344	620448	620552	620656	620760	620864	620968	1072	104
8	1176	1280	1384	1488	1592	1695	1799	1903	2007	2110	104
9	2214	2318	2421	2525	2628	2732	2835	2939	3042	3146	104
420	623249	623353	623456	623559	623663	623766	623869	623973	624076	624179	103
1	4282	4385	4488	4591	4695	4798	4901	5004	5107	5210	103
2	5312	5415	5518	5621	5724	5827	5929	6032	6135	6238	103
3	6340	6443	6546	6648	6751	6853	6956	7058	7161	7263	103
4	7366	7468	7571	7673	7775	7878	7980	8082	8185	8287	102
5	8389	8491	8593	8695	8797	8900	9002	9104	9206	9308	102
6	9410	9512	9613	9715	9817	9919	630021	630123	630224	630326	102
7	630428	630530	630631	630733	630835	630936	1038	1139	1241	1342	102
8	1444	1545	1647	1748	1849	1951	2052	2153	2255	2356	101
9	2457	2559	2660	2761	2862	2963	3064	3165	3266	3367	101
430	633468	633569	633670	633771	633872	633973	634074	634175	634276	634376	101
1	4477	4578	4679	4779	4880	4981	5081	5182	5283	5383	101
2	5484	5584	5685	5785	5886	5986	6087	6187	6287	6388	100
3	6488	6588	6688	6789	6889	6989	7089	7189	7290	7390	100
4	7490	7590	7690	7790	7890	7990	8090	8190	8290	8389	100
5	8489	8589	8689	8789	8888	8988	9088	9188	9287	9387	100
6	9486	9586	9686	9785	9885	9984	640084	640183	640283	640382	99
7	640481	640581	640680	640779	640879	640978	1077	1177	1276	1375	99
8	1474	1573	1672	1771	1871	1970	2069	2168	2267	2366	99
9	2465	2563	2662	2761	2860	2959	3058	3156	3255	3354	99
440	643453	643551	643650	643749	643847	643946	644044	644148	644242	644340	98
1	4439	4537	4636	4734	4832	4931	5029	5127	5226	5324	98
2	5422	5521	5619	5717	5815	5913	6011	6110	6208	6306	98
3	6404	6502	6600	6698	6796	6894	6992	7089	7187	7285	98
4	7383	7481	7579	7676	7774	7872	7969	8067	8165	8262	98
5	8360	8458	8555	8653	8750	8848	8945	9043	9140	9237	97
6	9335	9432	9530	9627	9724	9821	9919	650016	650113	650210	97
7	650308	650405	650502	650599	650696	650793	650890	0987	1084	1181	97
8	1278	1375	1472	1569	1666	1762	1859	1956	2053	2150	97
9	2246	2343	2440	2536	2633	2730	2826	2923	3019	3116	97
450	653213	653309	653405	653502	653598	653695	653791	653888	653984	654080	96
1	4177	4273	4369	4465	4562	4658	4754	4850	4946	5042	96
2	5138	5235	5331	5427	5523	5619	5715	5810	5906	6002	96
3	6098	6194	6290	6386	6482	6577	6673	6769	6864	6960	96
4	7056	7152	7247	7343	7438	7584	7629	7725	7820	7916	96
5	8011	8107	8202	8298	8393	8488	8584	8679	8774	8870	95
6	8965	9060	9155	9250	9346	9441	9536	9631	9726	9821	95
7	9916	660011	660106	660201	660296	660391	660486	660581	660676	660771	95
8	660865	0960	1055	1150	1245	1339	1434	1529	1623	1718	95
9	1813	1907	2002	2096	2191	2296	2380	2475	2509	2663	95
No.	0	1	2	3	4	5	6	7	8	9	Diff

No.	0	1	2	3	4	5	6	7	8	9	Diff
460	662758	662852	662947	663041	663135	663230	663324	663418	663512	663607	94
1	3701	3795	3889	3983	4078	4172	4266	4360	4454	4548	94
2	4642	4736	4830	4924	5018	5112	5206	5299	5393	5487	94
3	5581	5675	5769	5862	5956	6050	6143	6237	6331	6424	94
4	6518	6612	6705	6799	6892	6986	7079	7173	7266	7360	94
5	7453	7546	7640	7733	7826	7920	8013	8106	8199	8293	93
6	8386	8479	8572	8665	8759	8852	8945	9038	9131	9224	93
7	9317	9410	9503	9596	9689	9782	9875	9967	670060	670153	93
8	670246	670339	670431	670524	670617	670710	670802	670895	0988	1080	93
9	1173	1265	1358	1451	1543	1636	1728	1821	1913	2005	93
470	672098	672190	672283	672375	672467	672560	672652	672744	672836	672929	92
1	3021	3113	3205	3297	3390	3482	3574	3666	3758	3850	92
2	3942	4034	4126	4218	4310	4402	4494	4586	4677	4769	92
3	4861	4953	5045	5137	5228	5320	5412	5503	5595	5687	92
4	5778	5870	5962	6053	6145	6236	6328	6419	6511	6602	92
5	6694	6785	6876	6968	7059	7151	7242	7333	7424	7516	91
6	7607	7698	7789	7881	7972	8063	8154	8245	8336	8427	91
7	8518	8609	8700	8791	8882	8973	9064	9155	9246	9337	91
8	9428	9519	9610	9700	9791	9882	9973	680063	680154	680245	91
9	680336	680426	680517	680607	680698	680789	680879	0970	1060	1151	91
480	681241	681332	681422	681513	681603	681693	681784	681874	681964	682055	90
1	2145	2235	2326	2416	2506	2596	2686	2777	2867	2957	90
2	3047	3137	3227	3317	3407	3497	3587	3677	3767	3857	90
3	3947	4037	4127	4217	4307	4396	4486	4576	4666	4756	90
4	4845	4935	5025	5114	5204	5294	5383	5473	5563	5652	90
5	5742	5831	5921	6010	6100	6189	6279	6368	6458	6547	89
6	6636	6726	6815	6904	6994	7083	7172	7261	7351	7440	89
7	7529	7618	7707	7796	7886	7975	8064	8153	8242	8331	89
8	8420	8509	8598	8687	8776	8865	8953	9042	9131	9220	89
9	9309	9398	9486	9575	9664	9753	9841	9930	690019	690107	89
490	690196	690285	690373	690462	690550	690639	690728	690816	690905	690993	89
1	1081	1170	1258	1347	1435	1524	1612	1700	1789	1877	88
2	1965	2053	2142	2230	2318	2406	2494	2583	2671	2759	88
3	2847	2935	3023	3111	3199	3287	3375	3463	3551	3639	88
4	3727	3815	3903	3991	4078	4166	4254	4342	4430	4517	88
5	4605	4693	4781	4868	4956	5044	5131	5219	5307	5394	88
6	5482	5569	5657	5744	5832	5919	6007	6094	6182	6269	87
7	6356	6444	6531	6618	6706	6793	6880	6968	7055	7142	87
8	7229	7317	7404	7491	7578	7665	7752	7839	7926	8014	87
9	8101	8188	8275	8362	8449	8535	8622	8709	8796	8883	87
500	698970	699057	699144	699231	699317	699404	699491	699578	699664	699751	87
1	9838	9924	700011	700098	700184	700271	700358	700444	700531	700617	87
2	700704	700790	0877	0963	1050	1136	1222	1309	1395	1482	86
3	1568	1654	1741	1827	1913	1999	2086	2172	2258	2344	86
4	2431	2517	2603	2689	2775	2861	2947	3033	3119	3205	86
5	3291	3377	3463	3549	3635	3721	3807	3893	3979	4065	86
6	4151	4236	4322	4408	4494	4579	4665	4751	4837	4922	86
7	5008	5094	5179	5265	5350	5436	5522	5607	5693	5778	86
8	5864	5949	6035	6120	6206	6291	6376	6462	6547	6632	85
9	6718	6803	6888	6974	7059	7144	7229	7315	7400	7485	85
510	707570	707655	707740	707826	707911	707996	708081	708166	708251	708336	85
1	8421	8506	8591	8676	8761	8846	8931	9015	9100	9185	85
2	9270	9355	9440	9524	9609	9694	9779	9863	9948	710033	85
3	710117	710202	710287	710371	710456	710540	710625	710710	710794	0879	85
4	0963	1048	1132	1217	1301	1385	1470	1554	1639	1723	84
5	1807	1892	1976	2060	2144	2229	2313	2397	2481	2566	84
6	2650	2734	2818	2902	2986	3070	3154	3238	3323	3407	84
7	3491	3575	3659	3742	3826	3910	3994	4078	4162	4246	84
8	4330	4414	4497	4581	4665	4749	4833	4916	5000	5084	84
9	5167	5251	5335	5418	5502	5586	5669	5753	5836	5920	84
No.	0	1	2	3	4	5	6	7	8	9	Diff

No.	0	1	2	3	4	5	6	7	8	9	Diff
520	716003	716087	716170	716254	716337	716421	716504	716588	716671	716754	83
1	6838	6921	7004	7088	7171	7254	7338	7421	7504	7587	83
2	7671	7754	7837	7920	8003	8086	8169	8253	8336	8419	83
3	8502	8585	8668	8751	8834	8917	9000	9083	9165	9248	83
4	9331	9414	9497	9580	9663	9745	9828	9911	9994	720077	83
5	720159	720242	720325	720407	720490	720573	720655	720738	720821	0903	83
6	0986	1068	1151	1233	1316	1398	1481	1563	1646	1728	82
7	1811	1893	1975	2058	2140	2222	2305	2387	2469	2552	82
8	2634	2716	2798	2881	2963	3045	3127	3209	3291	3374	82
9	3456	3538	3620	3702	3784	3866	3948	4030	4112	4194	82
530	724276	724358	724440	724522	724604	724685	724767	724849	724931	725013	82
1	5095	5176	5258	5340	5422	5503	5585	5667	5748	5830	82
2	5912	5993	6075	6156	6238	6320	6401	6483	6564	6646	82
3	6727	6809	6890	6972	7053	7134	7216	7297	7379	7460	81
4	7541	7623	7704	7785	7866	7948	8029	8110	8191	8273	81
5	8354	8435	8516	8597	8678	8759	8841	8922	9003	9084	81
6	9165	9246	9327	9408	9489	9570	9651	9732	9813	9893	81
7	9974	730055	730136	730217	730298	730378	730459	730540	730621	730702	81
8	730782	0863	0944	1024	1105	1186	1266	1347	1428	1508	81
9	1589	1669	1750	1830	1911	1991	2072	2152	2233	2313	81
540	732394	732474	732555	732635	732715	732796	732876	732956	733037	733117	80
1	3197	3278	3358	3438	3518	3598	3679	3759	3839	3919	80
2	3999	4079	4160	4240	4320	4400	4480	4560	4640	4720	80
3	4800	4880	4960	5040	5120	5200	5279	5359	5439	5519	80
4	5599	5679	5759	5838	5918	5998	6078	6157	6237	6317	80
5	6397	6476	6556	6635	6715	6795	6874	6954	7034	7113	80
6	7193	7272	7352	7431	7511	7590	7670	7749	7829	7908	79
7	7987	8067	8146	8225	8305	8384	8463	8543	8622	8701	79
8	8781	8860	8939	9018	9097	9177	9256	9335	9414	9493	79
9	9572	9651	9731	9810	9889	9968	740047	740126	740205	740284	79
550	740363	740442	740521	740600	740678	740757	740836	740915	740994	741073	79
1	1152	1230	1309	1388	1467	1546	1624	1703	1782	1860	79
2	1939	2018	2096	2175	2254	2332	2411	2489	2568	2647	79
3	2725	2804	2882	2961	3039	3118	3196	3275	3353	3431	78
4	3510	3588	3667	3745	3823	3902	3980	4058	4136	4215	78
5	4293	4371	4449	4528	4606	4684	4762	4840	4919	4997	78
6	5075	5153	5231	5309	5387	5465	5543	5621	5699	5777	78
7	5855	5933	6011	6089	6167	6245	6323	6401	6479	6556	78
8	6634	6712	6790	6868	6945	7023	7101	7179	7256	7334	78
9	7412	7489	7567	7645	7722	7800	7878	7955	8033	8110	78
560	748188	748266	748343	748421	748498	748576	748653	748731	748808	748885	77
1	8963	9040	9118	9195	9272	9350	9427	9504	9582	9659	77
2	9736	9814	9891	9968	750045	750123	750200	750277	750354	750431	77
3	750508	750586	750663	750740	0817	0894	0971	1048	1125	1202	77
4	1279	1356	1433	1510	1587	1664	1741	1818	1895	1972	77
5	2048	2125	2202	2279	2356	2433	2509	2586	2663	2740	77
6	2816	2893	2970	3047	3123	3200	3277	3353	3430	3506	77
7	3583	3660	3736	3813	3889	3966	4042	4119	4195	4272	77
8	4348	4425	4501	4578	4654	4730	4807	4883	4960	5036	76
9	5112	5189	5265	5341	5417	5494	5570	5646	5722	5799	76
570	755875	755951	756027	756103	756180	756256	756332	756408	756484	756560	76
1	6636	6712	6788	6864	6940	7016	7092	7168	7244	7320	76
2	7396	7472	7548	7624	7700	7775	7851	7927	8003	8079	76
3	8155	8230	8306	8382	8458	8533	8609	8685	8761	8836	76
4	8912	8988	9063	9139	9214	9290	9366	9441	9517	9592	76
5	9668	9743	9819	9894	9970	760045	760121	760196	760272	760347	75
6	760422	760498	760573	760649	760724	0799	0875	0950	1025	1101	75
7	1176	1251	1326	1402	1477	1552	1627	1702	1778	1853	75
8	1928	2003	2078	2153	2228	2303	2378	2453	2529	2604	75
9	2679	2754	2829	2904	2978	3053	3128	3203	3278	3353	75
No.	0	1	2	3	4	5	6	7	8	9	Diff

No.	0	1	2	3	4	5	6	7	8	9	Diff
580	763428	763503	763578	763653	763727	763802	763877	763952	764027	764101	75
1	4176	4251	4326	4400	4475	4550	4624	4699	4774	4848	75
2	4923	4998	5072	5147	5221	5296	5370	5445	5520	5594	75
3	5669	5743	5818	5892	5966	6041	6115	6190	6264	6338	74
4	6413	6487	6562	6636	6710	6785	6859	6933	7007	7082	74
5	7156	7230	7304	7379	7453	7527	7601	7675	7749	7823	74
6	7898	7972	8046	8120	8194	8268	8342	8416	8490	8564	74
7	8638	8712	8786	8860	8934	9008	9082	9156	9230	9303	74
8	9377	9451	9525	9599	9673	9746	9820	9894	9968	770042	74
9	770115	770189	770263	770336	770410	770484	770557	770631	770705	0778	74
590	770852	770926	770999	771073	771146	771220	771293	771367	771440	771514	74
1	1587	1661	1734	1808	1881	1955	2028	2102	2175	2248	73
2	2322	2395	2468	2542	2615	2688	2762	2835	2908	2981	73
3	3055	3128	3201	3274	3348	3421	3494	3567	3640	3713	73
4	3786	3860	3933	4006	4079	4152	4225	4298	4371	4444	73
5	4517	4590	4663	4736	4809	4882	4955	5028	5100	5173	73
6	5246	5319	5392	5465	5538	5610	5683	5756	5829	5902	73
7	5974	6047	6120	6193	6265	6338	6411	6483	6556	6629	73
8	6701	6774	6846	6919	6992	7064	7137	7209	7282	7354	73
9	7427	7499	7572	7644	7717	7789	7862	7934	8006	8079	72
600	778151	778224	778296	778368	778441	778513	778585	778658	778730	778802	72
1	8874	8947	9019	9091	9163	9236	9308	9380	9452	9524	72
2	9596	9669	9741	9813	9885	9957	780029	780101	780173	780245	72
3	780317	780389	780461	780533	780605	780677	0749	0821	0893	0965	72
4	1037	1109	1181	1253	1324	1396	1468	1540	1612	1684	72
5	1755	1827	1899	1971	2042	2114	2186	2258	2329	2401	72
6	2473	2544	2616	2688	2759	2831	2902	2974	3046	3117	72
7	3189	3260	3332	3403	3475	3546	3618	3689	3761	3832	71
8	3904	3975	4046	4118	4189	4261	4332	4403	4475	4546	71
9	4617	4689	4760	4831	4902	4974	5045	5116	5187	5259	71
610	785330	785401	785472	785542	785615	785686	785757	785828	785899	785970	71
1	6041	6112	6183	6254	6325	6396	6467	6538	6609	6680	71
2	6751	6822	6893	6964	7035	7106	7177	7248	7319	7390	71
3	7460	7531	7602	7673	7744	7815	7885	7956	8027	8098	71
4	8168	8239	8310	8381	8451	8522	8593	8663	8734	8804	71
5	8875	8946	9016	9087	9157	9228	9299	9369	9440	9510	71
6	9581	9651	9722	9792	9863	9933	790004	790074	790144	790215	70
7	790285	790356	790426	790496	790567	790637	0707	0778	0848	0918	70
8	0988	1059	1129	1199	1269	1340	1410	1480	1550	1620	70
9	1691	1761	1831	1901	1971	2041	2111	2181	2252	2322	70
620	792392	792462	792532	792602	792672	792742	792812	792882	792952	793022	70
1	3092	3162	3231	3301	3371	3441	3511	3581	3651	3721	70
2	3790	3860	3930	4000	4070	4139	4209	4279	4349	4418	70
3	4488	4558	4627	4697	4767	4836	4906	4976	5045	4115	70
4	5185	5254	5824	5393	5463	5532	5602	5672	5741	5811	70
5	5880	5949	6019	6088	6158	6227	6297	6366	6436	6505	69
6	6574	6644	6713	6782	6852	6921	6990	7060	7129	7198	69
7	7268	7337	7406	7475	7545	7614	7683	7752	7821	7890	69
8	7960	8029	8098	8167	8236	8305	8374	8443	8513	8582	69
9	8651	8720	8789	8858	8927	8996	9065	9134	9203	9272	69
630	799341	799409	799478	799547	799616	799685	799754	799823	799892	799961	69
1	800029	800098	800167	800236	800305	800373	800442	800511	800580	800648	69
2	0717	0786	0854	0923	0992	1061	1129	1198	1266	1335	69
3	1404	1472	1541	1609	1678	1747	1815	1884	1952	2021	69
4	2089	2158	2226	2295	2363	2432	2500	2568	2637	2705	68
5	2774	2842	2910	2979	3047	3116	3184	3252	3321	3389	68
6	3457	3525	3594	3662	3730	3798	3867	3935	4003	4071	68
7	4139	4208	4276	4344	4412	4480	4548	4616	4685	4753	68
8	4821	4889	4957	5025	5093	5161	5229	5297	5365	5433	68
9	5501	5569	5637	5705	5773	5841	5908	5976	6044	6112	68
No.	0	1	2	3	4	5	6	7	8	9	Diff

No.	0	1	2	3	4	5	6	7	8	9	Diff
640	806180	806248	806316	806384	806451	806519	806587	806655	806723	806790	68
1	6858	6926	6994	7061	7129	7197	7264	7332	7400	7467	68
2	7535	7603	7670	7738	7806	7873	7941	8008	8076	8143	68
3	8211	8279	8346	8414	8481	8549	8616	8684	8751	8818	67
4	8886	8953	9021	9088	9156	9223	9290	9358	9425	9492	67
5	9560	9627	9694	9762	9829	9896	9964	810031	810098	810165	67
6	810233	810300	810367	810434	810501	810569	810636	0703	0770	0837	67
7	0904	0971	1039	1106	1173	1240	1307	1374	1441	1508	67
8	1575	1642	1709	1776	1843	1910	1977	2044	2111	2178	67
9	2245	2312	2379	2445	2512	2579	2646	2713	2780	2847	67
650	812913	812980	813047	813114	813181	813247	813314	813381	813448	813514	67
1	3581	3648	3714	3781	3848	3914	3981	4048	4114	4181	67
2	4248	4314	4381	4447	4514	4581	4647	4714	4780	4847	67
3	4913	4980	5046	5113	5179	5246	5312	5378	5445	5511	66
4	5578	5644	5711	5777	5843	5910	5976	6042	6109	6175	66
5	6241	6308	6374	6440	6506	6573	6639	6705	6771	6838	66
6	6904	6970	7036	7102	7169	7235	7301	7367	7433	7499	66
7	7565	7631	7698	7764	7830	7896	7962	8028	8094	8160	66
8	8226	8292	8358	8424	8490	8556	8622	8688	8754	8820	66
9	8885	8951	9017	9083	9149	9215	9281	9346	9412	9478	66
660	819544	819610	819676	819741	819807	819873	819939	820004	820070	820136	66
1	820201	820267	820333	820399	820464	820530	820595	0661	0727	0792	66
2	0858	0924	0989	1055	1120	1186	1251	1317	1382	1448	66
3	1514	1579	1645	1710	1775	1841	1906	1972	2037	2103	65
4	2168	2233	2299	2364	2430	2495	2560	2626	2691	2756	65
5	2822	2887	2952	3018	3083	3148	3213	3279	3344	3409	65
6	3474	3539	3605	3670	3735	3800	3865	3930	3996	4061	65
7	4126	4191	4256	4321	4386	4451	4516	4581	4646	4711	65
8	4776	4841	4906	4971	5036	5101	5166	5231	6296	5361	65
9	5426	5491	5556	5621	5686	5751	5815	5880	5945	6010	65
670	826075	826140	826204	826269	826334	826399	826464	826528	826593	826658	65
1	6723	6787	6852	6917	6981	7046	7111	7175	7240	7305	65
2	7369	7434	7499	7563	7628	7692	7757	7821	7886	7951	65
3	8015	8080	8144	8209	8273	8338	8402	8467	8531	8595	64
4	8660	8724	8789	8853	8918	8982	9046	9111	9175	9239	64
5	9304	9368	9432	9497	9561	9625	9690	9754	9818	9882	64
6	9947	830011	830075	830139	830204	830268	830332	830396	830460	830525	64
7	830589	0653	0717	0781	0845	0909	0973	1037	1102	1166	64
8	1230	1294	1358	1422	1486	1550	1614	1678	1742	1806	64
9	1870	1934	1998	2062	2126	2189	2253	2317	2381	2445	64
680	832509	832573	832637	832700	832764	832828	832892	832956	833020	833083	64
1	3147	3211	3275	3338	3402	3466	3530	3593	3657	3721	64
2	3784	3848	3912	3975	4039	4103	4166	4230	4294	4357	64
3	4421	4484	4548	4611	4675	4739	4802	4866	4929	4993	64
4	5056	5120	5183	5247	5310	5373	5437	5500	5564	5627	63
5	5691	5754	5817	5881	5944	6007	6071	6134	6197	6261	63
6	6324	6387	6451	6514	6577	6641	6704	6767	6830	6894	63
7	6957	7020	7083	7146	7210	7273	7336	7399	7462	7525	63
8	7588	7652	7715	7778	7841	7904	7967	8030	8093	8156	63
9	8219	8282	8345	8408	8471	8534	8597	8660	8723	8786	63
690	838849	838912	838975	839038	839101	839164	839227	839289	839352	839415	63
1	9478	9541	9604	9667	9729	9792	9855	9918	9981	840043	63
2	840106	840169	840232	840294	840357	840420	840482	840545	840608	0671	63
3	0733	0796	0859	0921	0984	1046	1109	1172	1234	1297	63
4	1359	1422	1485	1547	1610	1672	1735	1797	1860	1922	63
5	1985	2047	2110	2172	2235	2297	2360	2422	2484	2547	62
6	2609	2672	2734	2796	2859	2921	2983	3046	3108	3170	62
7	3233	3295	3357	3420	3482	3544	3606	3669	3731	3793	62
8	3855	3918	3980	4042	4104	4166	4229	4291	4353	4415	62
9	4477	4539	4601	4664	4726	4788	4850	4912	4974	5036	62
No.	0	1	2	3	4	5	6	7	8	9	Diff

No.	0	1	2	3	4	5	6	7	8	9	Diff
700	845098	845160	845222	845284	845346	845408	845470	845532	845594	845656	62
1	5718	5780	5842	5904	5966	6028	6090	6151	6213	6275	62
2	6337	6399	6461	6523	6585	6646	6708	6770	6832	6894	62
3	6955	7017	7079	7141	7202	7264	7326	7388	7449	7511	62
4	7573	7634	7696	7758	7819	7881	7943	8004	8066	8128	62
5	8189	8251	8312	8374	8435	8497	8559	8620	8682	8743	62
6	8805	8866	8928	8989	9051	9112	9174	9235	9297	9358	61
7	9419	9481	9542	9604	9665	9726	9788	9849	9911	9972	61
8	850033	850095	850156	850217	850279	850340	850401	850462	850524	850585	61
9	0646	0707	0769	0830	0891	0952	1014	1075	1136	1197	61
710	851258	851320	851381	851442	851503	851564	851625	851686	851747	851809	61
1	1870	1931	1992	2053	2114	2175	2236	2297	2358	2419	61
2	2480	2541	2602	2663	2724	2785	2846	2907	2968	3029	61
3	3090	3150	3211	3272	3333	3394	3455	3516	3577	3637	61
4	3698	3759	3820	3881	3941	4002	4063	4124	4185	4245	61
5	4306	4367	4428	4488	4549	4610	4670	4731	4792	4852	61
6	4913	4974	5034	5095	5156	5216	5277	5337	5398	5459	61
7	5519	5580	5640	5701	5761	5822	5882	5943	6003	6064	61
8	6124	6185	6245	6306	6366	6427	6487	6548	6608	6668	60
9	6729	6789	6850	6910	6970	7031	7091	7152	7212	7272	60
720	857332	857393	857453	857513	857574	857634	857694	857755	857815	857875	60
1	7935	7995	8056	8116	8176	8236	8297	8357	8417	8477	60
2	8537	8597	8657	8718	8778	8838	8898	8958	9018	9078	60
3	9138	9198	9258	9318	9379	9439	9499	9559	9619	9679	60
4	9739	9799	9859	9918	9978	860038	860098	860158	860218	860278	60
5	860338	860398	860458	860518	860578	0637	0697	0757	0817	0877	60
6	0937	0996	1056	1116	1176	1236	1295	1355	1415	1475	60
7	1534	1594	1654	1714	1773	1833	1893	1952	2012	2072	60
8	2131	2191	2251	2310	2370	2430	2489	2549	2608	2668	60
9	2728	2787	2847	2906	2966	3025	3085	3144	3204	3263	60
730	863323	863382	863442	863501	863561	863620	863680	863739	863799	863858	59
1	3917	3977	4036	4096	4155	4214	4274	4333	4392	4452	59
2	4511	4570	4630	4689	4748	4808	4867	4926	4985	5045	59
3	5104	5163	5222	5282	5341	5400	5459	5519	5578	5637	59
4	5696	5755	5814	5874	5933	5992	6051	6110	6169	6228	59
5	6287	6346	6405	6465	6524	6583	6642	6701	6760	6819	59
6	6878	6937	6996	7055	7114	7173	7232	7291	7350	7409	59
7	7467	7526	7585	7644	7703	7762	7821	7880	7939	7998	59
8	8056	8115	8174	8233	8292	8350	8409	8468	8527	8586	59
9	8644	8703	8762	8821	8879	8938	8997	9056	9114	9173	59
740	869232	869290	869349	869408	869466	869525	869584	869642	869701	869760	59
1	9818	9877	9935	9994	870053	870111	870170	870228	870287	870345	59
2	870404	870462	870521	870579	0638	0696	0755	0813	0872	0930	58
3	0989	1047	1106	1164	1223	1281	1339	1398	1456	1515	58
4	1573	1631	1690	1748	1806	1865	1923	1981	2040	2098	58
5	2156	2215	2273	2331	2389	2448	2506	2564	2622	2681	58
6	2739	2797	2855	2913	2972	3030	3088	3146	3204	3262	58
7	3321	3379	3437	3495	3553	3611	3669	3727	3785	3844	58
8	3902	3960	4018	4076	4134	4192	4250	4308	4366	4424	58
9	4482	4540	4598	4656	4714	4772	4830	4888	4945	5003	58
750	875061	875119	875177	875235	875293	875351	875409	875466	875524	875582	58
1	5640	5698	5756	5813	5871	5929	5987	6045	6102	6160	58
2	6218	6276	6333	6391	6449	6507	6564	6622	6680	6737	58
3	6795	6853	6910	6968	7026	7083	7141	7199	7256	7314	58
4	7371	7429	7487	7544	7602	7659	7717	7774	7832	7889	58
5	7947	8004	8062	8119	8177	8234	8292	8349	8407	8464	57
6	8522	8579	8637	8694	8752	8809	8866	8924	8981	9039	57
7	9096	9153	9211	9268	9325	9383	9440	9497	9555	9612	57
8	9669	9726	9784	9841	9898	9956	880013	880070	880127	880185	57
9	880242	880299	880356	880413	880471	880528	0585	0642	0699	0756	57
No.	0	1	2	3	4	5	6	7	8	9	Diff

No.	0	1	2	3	4	5	6	7	8	9	Diff
760	880814	880871	880928	880985	881042	881099	881156	881213	881271	881328	57
1	1385	1442	1499	1556	1613	1670	1727	1784	1841	1898	57
2	1955	2012	2069	2126	2183	2240	2297	2354	2411	2468	57
3	2525	2581	2638	2695	2752	2809	2866	2923	2980	3037	57
4	3093	3150	3207	3264	3321	3377	3434	3491	3548	3605	57
5	3661	3718	3775	3832	3888	3945	4002	4059	4115	4172	57
6	4229	4285	4342	4399	4455	4512	4569	4625	4682	4739	57
7	4795	4852	4909	4965	5022	5078	5135	5192	5248	5305	57
8	5361	5418	5474	5531	5587	5644	5700	5757	5813	5870	57
9	5926	5983	6039	6096	6152	6209	6265	6321	6378	6434	56
770	886491	886547	886604	886660	886716	886773	886829	886885	886942	886998	56
1	7054	7111	7167	7223	7280	7336	7392	7449	7505	7561	56
2	7617	7674	7730	7786	7842	7898	7955	8011	8067	8123	56
3	8179	8236	8292	8348	8404	8460	8516	8573	8629	8685	56
4	8741	8797	8853	8909	8965	9021	9077	9134	9190	9246	56
5	9302	9358	9414	9470	9526	9582	9638	9694	9750	9806	56
6	9862	9918	9974	890030	890086	890141	890197	890253	890309	890365	56
7	890421	890477	890533	0589	0645	0700	0756	0812	0868	0924	56
8	0980	1035	1091	1147	1203	1259	1314	1370	1426	1482	56
9	1537	1593	1649	1705	1760	1816	1872	1928	1983	2039	56
780	892095	892150	892206	892262	892317	892373	892429	892484	892540	892595	56
1	2651	2707	2762	2818	2873	2929	2985	3040	3096	3151	56
2	3207	3262	3318	3373	3429	3484	3540	3595	3651	3706	56
3	3762	3817	3873	3928	3984	4039	4094	4150	4205	4261	55
4	4316	4371	4427	4482	4538	4593	4648	4704	4759	4814	55
5	4870	4925	4980	5036	5091	5146	5201	5257	5312	5367	55
6	5423	5478	5533	5588	5644	5699	5754	5809	5864	5920	55
7	5975	6030	6085	6140	6195	6251	6306	6361	6416	6471	55
8	6526	6581	6636	6692	6747	6802	6857	6912	6967	7022	55
9	7077	7132	7187	7242	7297	7352	7407	7462	7517	7572	55
790	897627	897682	897737	897792	897847	897902	897957	898012	898067	898122	55
1	8176	8231	8286	8341	8396	8451	8506	8561	8615	8670	55
2	8725	8780	8835	8890	8944	8999	9054	9109	9164	9218	55
3	9273	9328	9383	9437	9492	9547	9602	9656	9711	9766	55
4	9821	9875	9930	9985	900039	900094	900149	900203	900258	900312	55
5	900367	900422	900476	900531	0586	0640	0695	0749	0804	0859	55
6	0913	0968	1022	1077	1131	1186	1240	1295	1349	1404	55
7	1458	1513	1567	1622	1676	1731	1785	1840	1894	1948	54
8	2003	2057	2112	2166	2221	2275	2329	2384	2438	2492	54
9	2547	2601	2655	2710	2764	2818	2873	2927	2981	3036	54
800	903090	903144	903199	903253	903307	903361	903416	903470	903524	903578	54
1	3633	3687	3741	3795	3849	3904	3958	4012	4066	4120	54
2	4174	4229	4283	4337	4391	4445	4499	4553	4607	4661	54
3	4716	4770	4824	4878	4932	4986	5040	5094	5148	5202	54
4	5256	5310	5364	5418	5472	5526	5580	5634	5688	5742	54
5	5796	5850	5904	5958	6012	6066	6119	6173	6227	6281	54
6	6335	6389	6443	6497	6551	6604	6658	6712	6766	6820	54
7	6874	6927	6981	7035	7089	7143	7196	7250	7304	7358	54
8	7411	7465	7519	7573	7626	7680	7734	7787	7841	7895	54
9	7949	8002	8056	8110	8163	8217	8270	8324	8378	8431	54
810	908485	908539	908592	908646	908699	908753	908807	908860	908914	908967	54
1	9021	9074	9128	9181	9235	9289	9342	9396	9449	9503	54
2	9556	9610	9663	9716	9770	9823	9877	9930	9984	910037	53
3	910091	910144	910197	910251	910304	910358	910411	910464	910518	0571	53
4	0624	0678	0731	0784	0838	0891	0944	0998	1051	1104	53
5	1158	1211	1264	1317	1371	1424	1477	1530	1584	1637	53
6	1690	1743	1797	1850	1903	1956	2009	2063	2116	2169	53
7	2222	2275	2328	2381	2435	2488	2541	2594	2647	2700	53
8	2753	2806	2859	2913	2966	3019	3072	3125	3178	3231	53
9	3284	3337	3390	3443	3496	3549	3602	3655	3708	3761	53
No.	0	1	2	3	4	5	6	7	8	9	Diff

No.	0	1	2	3	4	5	6	7	8	9	Diff
820	913814	913867	913920	913973	914026	914079	914132	914184	914237	914290	53
1	4343	4396	4449	4502	4555	4608	4660	4713	4766	4819	53
2	4872	4925	4977	5030	5083	5136	5189	5241	5294	5347	53
3	5400	5453	5505	5558	5611	5664	5716	5769	5822	5875	53
4	5927	5980	6033	6085	6138	6191	6243	6296	6349	6401	53
5	6454	6507	6559	6612	6664	6717	6770	6822	6875	6927	53
6	6980	7033	7085	7138	7190	7243	7295	7348	7400	7453	53
7	7506	7558	7611	7663	7716	7768	7820	7873	7925	7978	52
8	8030	8083	8135	8188	8240	8293	8345	8397	8450	8502	52
9	8555	8607	8659	8712	8764	8816	8869	8921	8973	9026	52
830	919078	919130	919183	919235	919287	919340	919392	919444	919496	919549	52
1	9601	9653	9706	9758	9810	9862	9914	9967	920019	920071	52
2	920123	920176	920228	920280	920332	920384	920436	920489	0541	0593	52
3	0645	0697	0749	0801	0853	0906	0958	1010	1062	1114	52
4	1166	1218	1270	1322	1374	1426	1478	1530	1582	1634	52
5	1686	1738	1790	1842	1894	1946	1998	2050	2102	2154	52
6	2206	2258	2310	2362	2414	2466	2518	2570	2622	2674	52
7	2725	2777	2829	2881	2933	2985	3037	3089	3140	3192	52
8	3244	3296	3348	3399	3451	3503	3555	3607	3658	3710	52
9	3762	3814	3865	3917	3969	4021	4072	4124	4176	4228	52
840	924279	924331	924383	924434	924486	924538	924589	924641	924693	924744	52
1	4796	4848	4899	4951	5003	5054	5106	5157	5209	5261	52
2	5312	5364	5415	5467	5518	5570	5621	5673	5725	5776	52
3	5828	5879	5931	5982	6034	6085	6137	6188	6240	6291	51
4	6342	6394	6445	6497	6548	6600	6651	6702	6754	6805	51
5	6857	6908	6959	7011	7062	7114	7165	7216	7268	7319	51
6	7370	7422	7473	7524	7576	7627	7678	7730	7781	7832	51
7	7883	7935	7986	8037	8088	8140	8191	8242	8293	8345	51
8	8396	8447	8498	8549	8601	8652	8703	8754	8805	8857	51
9	8908	8959	9010	9061	9112	9163	9215	9266	9317	9368	51
850	929419	929470	929521	929572	929623	929674	929725	929776	929827	929879	51
1	9930	9981	930032	930083	930134	930185	930236	930287	930338	930389	51
2	930440	930491	0542	0592	0643	0694	0745	0796	0847	0898	51
3	0949	1000	1051	1102	1153	1204	1254	1305	1356	1407	51
4	1458	1509	1560	1610	1661	1712	1763	1814	1865	1915	51
5	1966	2017	2068	2118	2169	2220	2271	2322	2372	2423	51
6	2474	2524	2575	2626	2677	2727	2778	2829	2879	2930	51
7	2981	3031	3082	3133	3183	3234	3285	3335	3386	3437	51
8	3487	3538	3589	3639	3690	3740	3791	3841	3892	3943	51
9	3993	4044	4094	4145	4195	4246	4296	4347	4397	4448	51
860	934498	934549	934599	934650	934700	934751	934801	934852	934902	934953	50
1	5003	5054	5104	5154	5205	5255	5306	5356	5406	5457	50
2	5507	5558	5608	5658	5709	5759	5809	5860	5910	5960	50
3	6011	6061	6111	6162	6212	6262	6313	6363	6413	6463	50
4	6514	6564	6614	6665	6715	6765	6815	6865	6916	6966	50
5	7016	7066	7117	7167	7217	7267	7317	7367	7418	7468	50
6	7518	7568	7618	7668	7718	7769	7819	7869	7919	7969	50
7	8019	8069	8119	8169	8219	8269	8320	8370	8420	8470	50
8	8520	8570	8620	8670	8720	8770	8820	8870	8920	8970	50
9	9020	9070	9120	9170	9220	9270	9320	9369	9419	9469	50
870	939519	939569	939619	939669	939719	939769	939819	939869	939918	939968	50
1	940018	940068	940118	940168	940218	940267	940317	940367	940417	940467	50
2	0516	0566	0616	0666	0716	0765	0815	0865	0915	0964	50
3	1014	1064	1114	1163	1213	1263	1313	1362	1412	1462	50
4	1511	1561	1611	1660	1710	1760	1809	1859	1909	1958	50
5	2008	2058	2107	2157	2207	2256	2306	2355	2405	2455	50
6	2504	2554	2603	2653	2702	2752	2801	2851	2901	2950	50
7	3000	3049	3099	3148	3198	3247	3297	3346	3396	3445	49
8	3495	3544	3593	3643	3692	3742	3791	3841	3890	3939	49
9	3989	4038	4088	4137	4186	4236	4285	4335	4384	4433	49
No.	0	1	2	3	4	5	6	7	8	9	Diff

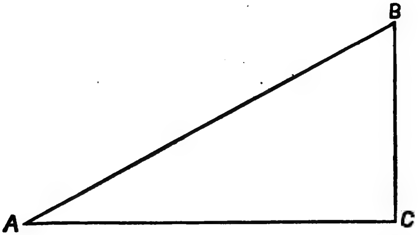
No.	0	1	2	3	4	5	6	7	8	9	Diff
880	944483	944532	944581	944631	944680	944729	944779	944828	944877	944927	49
1	4976	5025	5074	5124	5173	5222	5272	5321	5370	5419	49
2	5469	5518	5567	5616	5665	5715	5764	5813	5862	5912	49
3	5961	6010	6059	6108	6157	6207	6256	6305	6354	6403	49
4	6452	6501	6551	6600	6649	6698	6747	6796	6845	6894	49
5	6943	6992	7041	7090	7140	7189	7238	7287	7336	7385	49
6	7434	7483	7532	7581	7630	7679	7728	7777	7826	7875	49
7	7924	7973	8022	8070	8119	8168	8217	8266	8315	8364	49
8	8413	8462	8511	8560	8609	8657	8706	8755	8804	8853	49
9	8902	8951	8999	9048	9097	9146	9195	9244	9292	9341	49
890	949390	949439	949488	949536	949585	949634	949683	949731	949780	949829	49
1	9878	9926	9975	950024	950073	950121	950170	950219	950267	950316	49
2	950365	950414	950462	0511	0560	0608	0657	0706	0754	0803	49
3	0851	0900	0949	0997	1046	1095	1143	1192	1240	1289	49
4	1338	1386	1435	1483	1532	1580	1629	1677	1726	1775	49
5	1823	1872	1920	1969	2017	2066	2114	2163	2211	2260	48
6	2308	2356	2405	2453	2502	2550	2599	2647	2696	2744	48
7	2792	2841	2889	2938	2986	3034	3083	3131	3180	3228	48
8	3276	3325	3373	3421	3470	3518	3566	3615	3663	3711	48
9	3760	3808	3856	3905	3953	4001	4049	4098	4146	4194	48
900	954243	954291	954339	954387	954435	954484	954532	954580	954628	954677	48
1	4725	4773	4821	4869	4918	4966	5014	5062	5110	5158	48
2	5207	5255	5303	5351	5399	5447	5495	5543	5592	5640	48
3	5688	5736	5784	5832	5880	5928	5976	6024	6072	6120	48
4	6168	6216	6265	6313	6361	6409	6457	6505	6553	6601	48
5	6649	6697	6745	6793	6840	6888	6936	6984	7032	7080	48
6	7128	7176	7224	7272	7320	7368	7416	7464	7512	7559	48
7	7607	7655	7703	7751	7799	7847	7894	7942	7990	8038	48
8	8086	8134	8181	8229	8277	8325	8373	8421	8468	8516	48
9	8564	8612	8659	8707	8755	8803	8850	8898	8946	8994	48
910	959041	959089	959137	959185	959232	959280	959328	959375	959423	959471	48
1	9518	9566	9614	9661	9709	9757	9804	9852	9900	9947	48
2	9995	960042	960090	960138	960185	960233	960281	960328	960376	960423	48
3	960471	0518	0566	0613	0661	0709	0756	0804	0851	0899	48
4	0946	0994	1041	1089	1136	1184	1231	1279	1326	1374	48
5	1421	1469	1516	1563	1611	1658	1706	1753	1801	1848	47
6	1895	1943	1990	2038	2085	2132	2180	2227	2275	2322	47
7	2369	2417	2464	2511	2559	2606	2653	2701	2748	2795	47
8	2843	2890	2937	2985	3032	3079	3126	3174	3221	3268	47
9	3316	3363	3410	3457	3504	3552	3599	3646	3693	3741	47
920	963788	963835	963882	963929	963977	964024	964071	964118	964165	964212	47
1	4260	4307	4354	4401	4448	4495	4542	4590	4637	4684	47
2	4731	4778	4825	4872	4919	4966	5013	5061	5108	5155	47
3	5202	5249	5296	5343	5390	5437	5484	5531	5578	5625	47
4	5672	5719	5766	5813	5860	5907	5954	6001	6048	6095	47
5	6142	6189	6236	6283	6329	6376	6423	6470	6517	6564	47
6	6611	6658	6705	6752	6799	6845	6892	6939	6986	7033	47
7	7080	7127	7173	7220	7267	7314	7361	7408	7454	7501	47
8	7548	7595	7642	7688	7735	7782	7829	7875	7922	7969	47
9	8016	8062	8109	8156	8203	8249	8296	8343	8390	8436	47
930	968483	968530	968576	968623	968670	968716	968763	968810	968856	968903	47
1	8950	8996	9043	9090	9136	9183	9229	9276	9323	9369	47
2	9416	9463	9509	9556	9602	9649	9695	9742	9789	9835	47
3	9882	9928	9975	970021	970068	970114	970161	970207	970254	970300	47
4	970347	970393	970440	0486	0533	0579	0626	0672	0719	0765	46
5	0812	0858	0904	0951	0997	1044	1090	1137	1183	1229	46
6	1276	1322	1369	1415	1461	1508	1554	1601	1647	1693	46
7	1740	1786	1832	1879	1925	1971	2018	2064	2110	2157	46
8	2203	2249	2295	2342	2388	2434	2481	2527	2573	2619	46
9	2666	2712	2758	2804	2851	2897	2943	2989	3035	3082	46
No.	0	1	2	3	4	5	6	7	8	9	Diff

No.	0	1	2	3	4	5	6	7	8	9	Diff
940	973128	973174	973220	973266	973313	973359	973405	973451	973497	973543	46
1	3590	3636	3682	3728	3774	3820	3866	3913	3959	4005	46
2	4051	4097	4143	4189	4235	4281	4327	4374	4420	4466	46
3	4512	4558	4604	4650	4696	4742	4788	4834	4880	4926	46
4	4972	5018	5064	5110	5156	5202	5248	5294	5340	5386	46
5	5432	5478	5524	5570	5616	5662	5707	5753	5799	5845	46
6	5891	5937	5983	6029	6075	6121	6167	6212	6258	6304	46
7	6350	6396	6442	6488	6533	6579	6625	6671	6717	6763	46
8	6808	6854	6900	6946	6992	7037	7083	7129	7175	7220	46
9	7266	7312	7358	7403	7449	7495	7541	7586	7632	7678	46
950	977724	977769	977815	977861	977906	977952	977998	978043	978089	978135	46
1	8181	8226	8272	8317	8363	8409	8454	8500	8546	8591	46
2	8637	8683	8728	8774	8819	8865	8911	8956	9002	9047	46
3	9093	9138	9184	9230	9275	9321	9366	9412	9457	9503	46
4	9548	9594	9639	9685	9730	9776	9821	9867	9912	9958	46
5	980003	980049	980094	980140	980185	980231	980276	980322	980367	980412	45
6	0458	0503	0549	0594	0640	0685	0730	0776	0821	0867	45
7	0912	0957	1003	1048	1093	1139	1184	1229	1275	1320	45
8	1366	1411	1456	1501	1547	1592	1637	1683	1728	1773	45
9	1819	1864	1909	1954	2000	2045	2090	2135	2181	2226	45
960	982271	982316	982362	982407	982452	982497	982543	982588	982633	982678	45
1	2723	2769	2814	2859	2904	2949	2994	3040	3085	3130	45
2	3175	3220	3265	3310	3356	3401	3446	3491	3536	3581	45
3	3626	3671	3716	3762	3807	3852	3897	3942	3987	4032	45
4	4077	4122	4167	4212	4257	4302	4347	4392	4437	4482	45
5	4527	4572	4617	4662	4707	4752	4797	4842	4887	4932	45
6	4977	5022	5067	5112	5157	5202	5247	5292	5337	5382	45
7	5426	5471	5516	5561	5606	5651	5696	5741	5786	5830	45
8	5875	5920	5965	6010	6055	6100	6144	6189	6234	6279	45
9	6324	6369	6413	6458	6503	6548	6593	6637	6682	6727	45
970	986772	986817	986861	986906	986951	986996	987040	987085	987130	987175	45
1	7219	7264	7309	7353	7398	7443	7488	7532	7577	7622	45
2	7666	7711	7756	7800	7845	7890	7934	7979	8024	8068	45
3	8113	8157	8202	8247	8291	8336	8381	8425	8470	8514	45
4	8559	8604	8648	8693	8737	8782	8826	8871	8916	8960	45
5	9005	9049	9094	9138	9183	9227	9272	9316	9361	9405	45
6	9450	9494	9539	9583	9628	9672	9717	9761	9806	9850	44
7	9895	9939	9983	990028	990072	990117	990161	990206	990250	990294	44
8	990339	990383	990428	0472	0516	0561	0605	0650	0694	0738	44
9	0783	0827	0871	0916	0960	1004	1049	1093	1137	1182	44
980	991226	991270	991315	991359	991403	991448	991492	991536	991580	991625	44
1	1669	1713	1758	1802	1846	1890	1935	1979	2023	2067	44
2	2111	2156	2200	2244	2288	2333	2377	2421	2465	2509	44
3	2554	2598	2642	2686	2730	2774	2819	2863	2907	2951	44
4	2995	3039	3083	3127	3172	3216	3260	3304	3348	3392	44
5	3436	3480	3524	3568	3613	3657	3701	3745	3789	3833	44
6	3877	3921	3965	4009	4053	4097	4141	4185	4229	4273	44
7	4317	4361	4405	4449	4493	4537	4581	4625	4669	4713	44
8	4757	4801	4845	4889	4933	4977	5021	5065	5108	5152	44
9	5196	5240	5284	5328	5372	5416	5460	5504	5547	5591	44
990	995635	995679	995723	995767	995811	995854	995898	995942	995986	996030	44
1	6074	6117	6161	6205	6249	6293	6337	6380	6424	6468	44
2	6512	6555	6599	6643	6687	6731	6774	6818	6862	6906	44
3	6949	6993	7037	7080	7124	7168	7212	7255	7299	7343	44
4	7386	7430	7474	7517	7561	7605	7648	7692	7736	7779	44
5	7823	7867	7910	7954	7998	8041	8085	8129	8172	8216	44
6	8259	8303	8347	8390	8434	8477	8521	8564	8608	8652	44
7	8695	8739	8782	8826	8869	8913	8956	9000	9043	9087	44
8	9131	9174	9218	9261	9305	9348	9392	9435	9479	9522	44
9	9565	9609	9652	9696	9739	9783	9826	9870	9913	9957	43
No.	0	1	2	3	4	5	6	7	8	9	Diff

LOGARITHMIC SINES AND TANGENTS.

When natural sines and tangents are used, it is necessary to perform tedious and often lengthy operations of multiplication and division. By the use of logarithmic sines and tangents, in conjunction with the logarithms of numbers, these operations are reduced to addition and subtraction.

The sines, cosines, tangents, and cotangents are found in the same manner in this table as in the table of natural sines and tangents.



FORMULÆ FOR SOLUTION OF RIGHT-ANGLED TRIANGLES.

Log. A C = log. cosine A + log. of A B + 10.
Log. A C = log. B C + 10 — log. tangent A.
Log. B C = log. sine A + log. A B — 10.
Log. B C = log. tang. A + log. A C — 10.
Log. A B = log. A C + 10 — log. cosine A.
Log. A B = log. B C + 10 — log. sine A.
Log. tang. A = log. B C + 10 — log. A C.
Log. sine A = log. B C + 10 — log. A B.

FORMULÆ FOR SOLUTION OF ANY PLANE TRIANGLE.

Sine of angle B : log. A C :: sine of A : log. B C.
Sine of angle A : log. B C :: sine of B : log. A C.

Thus, if the angle A = 30°, the angle B = 60°, and the angle C = 90°, and the side B C = 200 ft. Then,

(log. sine B + log. B C) — sine A = log. of A C,
or (9·937531+ 2·301030) — 9·698970 = 2·539591, or
log. of 346.4+. Hence, 346·4+ ft. = side A C

0 Degree.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	0·000000		10·000000		0·000000		Infinite.	60
1	6·463726	501717	000000	00	6·463726	501717	13·536274	59
2	764756	293485	000000	00	764756	293483	235244	58
3	940847	208231	000000	00	940847	208231	059153	57
4	7.065786	161517	000000	00	7·065786	161517	12·934214	56
5	162696	131968	000000	00	162696	131969	837304	55
6	241877	111575	9·999999	01	241878	111578	758122	54
7	308824	96653	999999	01	308825	99653	691175	53
8	366816	85254	999999	01	366817	85254	633183	52
9	417968	76263	999999	01	417970	76263	582030	51
10	463725	68988	999998	01	463727	68988	536273	50
11	7·505118	62981	9·999998	01	7·505120	62981	12·494880	49
12	542906	57936	999997	01	542909	57933	457091	48
13	577668	53641	999997	01	577672	53642	422328	47
14	609853	49938	999996	01	609857	49939	390143	46
15	639816	46714	999996	01	639820	46715	360180	45
16	667845	43881	999995	01	667849	43882	332151	44
17	694173	41372	999995	01	694179	41373	305821	43
18	718997	39135	999994	01	719003	39136	280997	42
19	742477	37127	999993	01	742484	37128	257516	41
20	764754	35315	999993	01	764761	35136	235239	40
21	7·785943	33672	9·999992	01	7·785951	33673	12·214049	39
22	806146	32175	999991	01	806155	32176	193845	38
23	825451	30805	999990	01	825460	30806	174540	37
24	843934	29547	999989	02	843944	29549	156056	36
25	861662	28388	999988	02	861674	28390	138326	35
26	878695	27317	999988	02	878708	27318	121292	34
27	895085	26323	999987	02	895099	26325	104901	33
28	910879	25399	999986	02	910894	25401	089106	32
29	926119	24538	999985	02	926134	24540	073866	31
30	940842	23733	999983	02	940858	23735	059142	30
31	7·955082	22980	9·999982	02	7·955100	22981	12·044900	29
32	968870	22273	999981	02	968889	22275	031111	28
33	982233	21608	999980	02	982253	21610	017747	27
34	995198	20981	999979	02	995219	20983	004781	26
35	8·007787	20390	999977	02	8.007809	20392	11·992191	25
36	020021	19831	999976	02	020045	19833	979955	24
37	031919	19302	999975	02	031945	19305	968055	23
38	043501	18801	999973	02	043527	18803	956473	22
39	054781	18325	999972	02	054809	18327	945191	21
40	065776	17872	999971	02	065806	17874	934194	20
41	8·076500	17441	9·999969	02	8·076531	17444	11·923469	19
42	086965	17031	999968	02	086997	17034	913003	18
43	097183	16639	999966	02	097217	16642	902783	17
44	107167	16265	999964	03	107202	16268	892797	16
45	116926	15908	999963	03	116963	15910	883037	15
46	126471	15566	999961	03	126510	15568	873490	14
47	135810	15238	999959	03	135851	15241	864149	13
48	144953	14924	999958	03	144996	14927	855004	12
49	153907	14622	999956	03	153952	14627	846048	11
50	162681	14333	999954	03	162727	14336	837273	10
51	8·171280	14054	9·999952	03	8·171328	14057	11·828672	9
52	179713	13786	999950	03	179763	13790	820237	8
53	187985	13529	999948	03	188036	13532	811964	7
54	196102	13280	999946	03	196156	13284	803844	6
55	204070	13041	999944	03	204126	13044	795874	5
56	211895	12810	999942	04	211953	12814	788047	4
57	219581	12587	999940	04	219641	12590	780359	3
58	227134	12372	999938	04	227195	12376	772805	2
59	234557	12164	999936	04	234621	12168	765379	1
60	241855	11963	999934	04	241921	11967	758079	0
	Cosine.		Sine.		Cotang.		Tang.	M.

89 Degrees.

1 Degree.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	8·241855	11963	9·999934	04	8·241921	11967	11·758098	60
1	249033	11768	999932	04	249102	11772	750835	59
2	256094	11580	999929	04	256165	11584	743879	58
3	263042	11398	999927	04	263115	11402	736885	57
4	269881	11221	999925	04	269956	11225	730044	56
5	276614	11050	999922	04	276691	11054	723309	55
6	283243	10883	999920	04	283323	10887	716677	54
7	289773	10721	999918	04	289856	10726	710144	53
8	296207	10565	999915	04	296292	10570	703708	52
9	302546	10413	999913	04	302634	10418	697366	51
10	308794	10266	999910	04	308884	10270	691116	50
11	8·314954	10122	9·999907	04	8·315046	10126	11·684954	49
12	321027	9982	999905	04	321122	9987	678878	48
13	327016	9847	999902	04	327114	9851	672886	47
14	332924	9714	999899	05	333025	9719	666975	46
15	338753	9586	999897	05	338856	9590	661144	45
16	344504	9460	999894	05	344610	9465	655390	44
17	350181	9338	999891	05	350289	9343	649711	43
18	355783	9219	999888	05	355895	9224	644105	42
19	361315	9103	999885	05	361430	9108	638570	41
20	366777	8990	999882	05	366895	8995	633105	40
21	8·372171	8880	9·999879	05	8·372292	8885	11·627708	39
22	377499	8772	999876	05	377622	8777	622378	38
23	382762	8667	999873	05	382889	8672	617111	37
24	387962	8564	999870	05	388092	8570	611908	36
25	393101	8464	999867	05	393234	8470	606766	35
26	398179	8366	999864	05	398315	8371	601685	34
27	403199	8271	999861	05	403338	8276	596662	33
28	408161	8177	999858	05	408304	8182	591696	32
29	413068	8086	999854	05	413213	8091	586787	31
30	417919	7996	999851	06	418068	8002	581932	30
31	8·422717	7909	9·999848	06	8·422869	7914	11·577131	29
32	427462	7823	999844	06	427618	7830	572382	28
33	432156	7740	999841	06	432315	7745	567685	27
34	436800	7657	999838	06	436962	7663	563038	26
35	441394	7577	999834	06	441560	7583	558440	25
36	445941	7499	999831	06	446110	7505	553890	24
37	450440	7422	999827	06	450613	7428	549387	23
38	454893	7346	999823	06	455070	7352	544930	22
39	459301	7273	999820	06	459481	7279	540519	21
40	463665	7200	999816	06	463849	7206	536151	20
41	8·467985	7129	9·999812	06	8·468172	7135	11·531828	19
42	472263	7060	999809	06	472454	7066	527546	18
43	476498	6991	999805	06	476693	6998	523307	17
44	480693	6924	999801	06	480892	6931	519108	16
45	484848	6859	999797	07	485050	6865	514950	15
46	488963	6794	999793	07	489170	6801	510830	14
47	493040	6731	999790	07	493250	6738	506750	13
48	497078	6669	999786	07	497293	6676	502707	12
49	501080	6608	999782	07	501298	6615	498702	11
50	505045	6548	999778	07	505267	6555	494733	10
51	8·508974	6489	9·999774	07	8·509200	6496	11·490800	9
52	512867	6431	999769	07	513098	6439	486902	8
53	516726	6375	999765	07	516961	6382	483039	7
54	520551	6319	999761	07	520790	6326	479210	6
55	524343	6264	999757	07	524586	6272	475414	5
56	528102	6211	999753	07	528349	6218	471651	4
57	531828	6158	999748	07	532080	6165	467920	3
58	535523	6106	999744	07	535779	6113	464221	2
59	539186	6055	999740	07	539447	6062	460553	1
60	542819	6004	999735	07	543084	6012	456916	0
	Cosine.		Sine.		Cotang.		Tang.	M.

88 Degrees.

2 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	8·542819	6004	9·999735	07	8·543084	6012	11·456916	60
1	546422	5955	999731	07	546691	5962	453309	59
2	549995	5906	999726	07	550268	5914	449732	58
3	553539	5858	999722	08	553817	5866	446183	57
4	557054	5811	999717	08	557336	5819	442664	56
5	560540	5765	999713	08	560828	5773	439172	55
6	563999	5719	999708	08	564291	5727	435709	54
7	567431	5674	999704	08	567727	5682	432273	53
8	570836	5630	999699	08	571137	5638	428863	52
9	574214	5587	999694	08	574520	5595	425480	51
10	577566	5544	999689	08	577877	5552	422123	50
11	8·580892	5502	9·999685	08	8·581208	5510	11·418792	49
12	584193	5460	999680	08	584514	5468	415486	48
13	587469	5419	999675	08	587795	5427	412205	47
14	590721	5379	999670	08	591051	5387	408949	46
15	593948	5339	999665	08	594283	5347	405717	45
16	597152	5300	999660	08	597492	5308	402508	44
17	600332	5261	999655	08	600677	5270	399323	43
18	603489	5223	999650	08	603839	5232	396161	42
19	606623	5186	999645	09	606978	5194	393022	41
20	609734	5149	999640	09	610094	5158	389906	40
21	8·612823	5112	9·999635	09	8·613189	5121	11·386811	39
22	615891	5076	999629	09	616262	5085	383738	38
23	618937	5041	999624	09	619313	5050	380687	37
24	621962	5006	999619	09	622343	5015	377657	36
25	624965	4972	999614	09	625352	4981	374648	35
26	627948	4938	999608	09	628340	4947	371660	34
27	630911	4904	999603	09	631308	4913	368692	33
28	633854	4871	999597	09	634256	4880	365744	32
29	636776	4839	999592	09	637184	4848	362816	31
30	639680	4806	999586	09	640093	4816	359907	30
31	8·642563	4775	9·999581	09	8·642982	4784	11·357018	29
32	645428	4743	999575	09	645853	4753	354147	28
33	648274	4712	999570	09	648704	4722	351296	27
34	651102	4682	999564	09	651537	4691	348463	26
35	653911	4652	999558	10	654352	4661	345648	25
36	656702	4622	999553	10	657149	4631	342851	24
37	659475	4592	999547	10	659928	4602	340072	23
38	662230	4563	999541	10	662689	4573	337311	22
39	664968	4535	999535	10	665433	4544	334567	21
40	667689	4506	999529	10	668160	4526	331840	20
41	8·670393	4479	9·999524	10	8·670870	4488	11·329130	19
42	673080	4451	999518	10	673563	4461	326437	18
43	675751	4424	999512	10	676239	4434	323761	17
44	678405	4397	999506	10	678900	4417	321100	16
45	681043	4370	999500	10	681544	4380	318456	15
46	683665	4344	999493	10	684172	4354	315828	14
47	686272	4318	999487	10	686784	4328	313216	13
48	688863	4292	999481	10	689381	4303	310619	12
49	691438	4267	999475	10	691963	4277	308037	11
50	693998	4242	999469	10	694529	4252	305471	10
51	8·696543	4217	9·999463	11	8·697081	4228	11·302919	9
52	699073	4192	999456	11	699617	4203	300383	8
53	701589	4168	999450	11	702139	4179	297861	7
54	704090	4144	999443	11	704646	4155	295354	6
55	706577	4121	999437	11	707140	4132	292860	5
56	709049	4097	999431	11	709618	4108	290382	4
57	711507	4074	999424	11	712083	4085	287917	3
58	713952	4051	999418	11	714534	4062	285465	2
59	716383	4029	999411	11	716972	4040	283028	1
60	718800	4006	999404	11	719396	4017	280604	0
	Cosine.		Sine.		Cotang.		Tang.	M.

87 Degrees.

3 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D	Cotang.	
0	8·718800	4006	9·999404	11	8·719396	4017	11·280604	60
1	721204	3984	999398	11	721806	3995	278194	59
2	723595	3962	999391	11	724204	3974	275796	58
3	725972	3941	999384	11	726588	3952	273412	57
4	728337	3919	999378	11	728959	3930	271041	56
5	730688	3898	999371	11	731317	3909	268683	55
6	733027	3877	999364	12	733663	3889	266337	54
7	735354	3857	999357	12	735996	3868	264004	53
8	737667	3836	999350	12	738317	3848	261683	52
9	739969	3816	999343	12	740626	3827	259374	51
10	742259	3796	999336	12	742922	3807	257078	50
11	8·744536	3776	9·999329	12	8·745207	3787	11·254793	49
12	746802	3756	999322	12	747479	3768	252521	48
13	749055	3737	999315	12	749740	3749	250260	47
14	751297	3717	999308	12	751989	3729	248011	46
15	753528	3698	999301	12	754227	3710	245773	45
16	755747	3679	999294	12	756453	3692	243547	44
17	757955	3661	999286	12	758668	3673	241332	43
18	760151	3642	999279	12	760872	3655	239128	42
19	762337	3624	999272	12	763065	3636	236935	41
20	764511	3606	999265	12	765246	3618	234754	40
21	8·766675	3588	9·999257	12	8·767417	3600	11·232583	39
22	768828	3570	999250	13	769578	3583	230422	38
23	770970	3553	999242	13	771727	3565	228273	37
24	773101	3535	999235	13	773866	3548	226134	36
25	775223	3518	999227	13	775995	3531	224005	35
26	777333	3501	999220	13	778114	3514	221886	34
27	779434	3484	999212	13	780222	3497	219778	33
28	781524	3467	999205	13	782320	3480	217680	32
29	783605	3451	999197	13	784408	3464	215592	31
30	785675	3431	999189	13	786486	3447	213514	30
31	8·787736	3418	9·999181	13	8·788554	3431	11·211446	29
32	789787	3402	999174	13	790613	3414	209387	28
33	791828	3386	999166	13	792662	3399	207338	27
34	793859	3370	999158	13	794701	3383	205299	26
35	795881	3354	999150	13	796731	3368	203269	25
36	797894	3339	999142	13	798752	3352	201248	24
37	799897	3323	999134	13	800763	3337	199237	23
38	801892	3308	999126	13	802765	3322	197235	22
39	803876	3293	999118	13	804758	3307	195242	21
40	805852	3278	999110	13	806742	3292	193258	20
41	8·807819	3263	9·999102	13	8·808717	3278	11·191283	19
42	809777	3249	999094	14	810683	3262	189317	18
43	811726	3234	999086	14	812641	3248	187359	17
44	813667	3219	999077	14	814589	3233	185411	16
45	815599	3205	999069	14	816529	3219	183471	15
46	817522	3191	999061	14	818461	3205	181539	14
47	819436	3177	999053	14	820384	3191	179616	13
48	821343	3163	999044	14	822298	3177	177702	12
49	823240	3149	999036	14	824205	3163	175795	11
50	825130	3135	999027	14	826103	3150	173897	10
51	8·827011	3122	9·999019	14	8·827992	3136	11·172008	9
52	828884	3108	999010	14	829874	3123	170126	8
53	830749	3095	999002	14	831748	3110	168252	7
54	832607	3082	998993	14	833613	3096	166387	6
55	834456	3069	998984	14	835471	3083	164529	5
56	836297	3056	998976	14	837321	3070	162679	4
57	838130	3043	998967	15	839163	3057	160837	3
58	839956	3030	998958	15	840998	3045	159002	2
59	841774	3017	998950	15	842825	3032	157175	1
60	843585	3000	998941	15	844644	3019	155356	0
	Cosine.		Sine.		Cotang.		Tang.	M.

86 Degrees.

4 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	8·843585	3005	9·998941	15	8·844644	3019	11·155356	60
1	845387	2992	998932	15	846455	3007	153545	59
2	847183	2980	998923	15	848260	2995	151740	58
3	848971	2967	998914	15	850057	2982	149943	57
4	850751	2955	998905	15	851846	2970	148154	56
5	852525	2943	998896	15	853628	2958	146372	55
6	854291	2931	998887	15	855403	2946	144597	54
7	856049	2919	998878	15	857171	2935	142829	53
8	857801	2907	998869	15	858932	2923	141068	52
9	859546	2896	998860	15	860686	2911	139314	51
10	861283	2884	998851	15	862433	2900	137567	50
11	8·863014	2873	9·998841	15	8·864173	2888	11·135827	49
12	864738	2861	998832	15	865906	2877	134094	48
13	866455	2850	998823	16	867632	2866	132368	47
14	868165	2839	998813	16	869351	2854	130649	46
15	869868	2828	998804	16	871064	2843	128936	45
16	871565	2817	998795	16	872770	2832	127230	44
17	873255	2806	998785	16	874469	2821	125531	43
18	874938	2795	998776	16	876162	2811	123838	42
19	876615	2786	998766	16	877849	2800	122151	41
20	878285	2773	998757	16	879529	2789	120471	40
21	8·879949	2763	9·998747	16	8·881202	2779	11·118798	39
22	881607	2752	998738	16	882869	2768	117131	38
23	883258	2742	998728	16	884530	2758	115470	37
24	884903	2731	998718	16	886185	2747	113815	36
25	886542	2721	998708	16	887833	2737	112167	35
26	888174	2711	998699	16	889476	2727	110524	34
27	889801	2700	998689	16	891112	2717	108888	33
28	891421	2690	998679	16	892742	2707	107258	32
29	893035	2680	998669	17	894366	2697	105634	31
30	894643	2670	998659	17	895984	2687	104016	30
31	8·896246	2660	9·998649	17	8·897596	2677	11·102404	29
32	897842	2651	998639	17	899203	2667	100797	28
33	899432	2641	998629	17	900803	2658	099197	27
34	901017	2631	998619	17	902398	2648	097602	26
35	902596	2622	998609	17	903987	2638	096013	25
36	904169	2612	998599	17	905570	2629	094430	24
37	905736	2603	998589	17	907147	2620	092853	23
38	907297	2593	998578	17	908719	2610	091281	22
39	908853	2584	998568	17	910285	2601	089715	21
40	910404	2575	998558	17	911846	2592	088154	20
41	8·911949	2566	9·998548	17	8·913401	2583	11·086599	19
42	913488	2556	998537	17	914951	2574	085049	18
43	915022	2547	998527	17	916495	2565	083505	17
44	916550	2538	998516	18	918034	2556	081966	16
45	918073	2529	998506	18	919568	2547	080432	15
46	919591	2520	998495	18	921096	2538	078904	14
47	921103	2512	998485	18	922619	2530	077381	13
48	922610	2503	998474	18	924136	2521	075864	12
49	924112	2494	998464	18	925649	2512	074351	11
50	925609	2486	998453	18	927156	2503	072844	10
51	8·927100	2477	9·998442	18	8·928658	2495	11·071342	9
52	928587	2469	998431	18	930155	2486	069845	8
53	930068	2460	998421	18	931647	2478	068353	7
54	931544	2452	998410	18	933134	2470	066866	6
55	933015	2443	998399	18	934616	2461	065384	5
56	934481	2435	998388	18	936093	2453	063907	4
57	935942	2427	998377	18	937565	2445	062435	3
58	937398	2419	998366	18	939032	2437	060968	2
59	938850	2411	998355	18	940494	2430	059506	1
60	940296	2403	998344	18	941952	2421	058048	0
	Cosine.		Sine.		Cotang.		Tang.	M.

85 Degrees.

5 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	8·940296	2403	9·998344	19	8·941952	2421	11·058048	60
1	941738	2394	998333	19	943404	2413	056596	59
2	943174	2387	998322	19	944852	2405	055148	58
3	944606	2379	998311	19	946295	2397	053705	57
4	946034	2371	998300	19	947734	2390	052266	56
5	947456	2363	998289	19	949168	2382	050832	55
6	948874	2355	998277	19	950597	2374	049403	54
7	950287	2348	998266	19	952021	2366	047979	53
8	951696	2340	998255	19	953441	2360	046559	52
9	953100	2332	998243	19	954856	2351	045144	51
10	954499	2325	998232	19	956267	2344	043733	50
11	8·955894	2317	9·998220	19	8·957674	2337	11·042326	49
12	957284	2310	998209	19	959075	2329	040925	48
13	958670	2302	998197	19	960473	2323	039527	47
14	960052	2295	998186	19	961866	2314	038134	46
15	961429	2288	998174	19	963255	2307	036745	45
16	962801	2280	998163	19	964639	2300	035361	44
17	964170	2273	998151	19	966019	2293	033981	43
18	965534	2266	998139	20	967394	2286	032606	42
19	966893	2259	998128	20	968766	2279	031234	41
20	968249	2252	998116	20	970133	2271	029867	40
21	8·969600	2244	9·998104	20	8·971496	2265	11·028504	39
22	970947	2238	998092	20	972855	2257	027145	38
23	972289	2231	998080	20	974209	2251	025791	37
24	973628	2224	998068	20	975560	2244	024440	36
25	974962	2217	998056	20	976906	2237	023094	35
26	976293	2210	998044	20	978248	2230	021752	34
27	977619	2203	998032	20	979586	2223	020414	33
28	978941	2197	998020	20	980921	2217	019079	32
29	980259	2190	998008	20	982251	2210	017749	31
30	981573	2183	997996	20	983577	2204	016423	30
31	8·982883	2177	9·997984	20	8·984899	2197	11·015101	29
32	984189	2170	997972	20	986217	2191	013783	28
33	985491	2163	997959	20	987532	2184	012468	27
34	986789	2157	997947	20	988842	2178	011158	26
35	988083	2150	997935	21	990149	2171	009851	25
36	989374	2144	997922	21	991451	2165	008549	24
37	990660	2138	997910	21	992750	2158	007250	23
38	991943	2131	997897	21	994045	2152	005955	22
39	993222	2125	997885	21	995337	2146	004663	21
40	994497	2119	997872	21	996624	2140	003376	20
41	8·995768	2112	9·997860	21	8·997908	2134	11·002092	19
42	997036	2106	997847	21	999188	2127	000812	18
43	998299	2100	997835	21	9·000465	2121	10·999535	17
44	999560	2094	997822	21	001738	2115	998262	16
45	9·000816	2087	997809	21	003007	2109	996993	15
46	002069	2082	997797	21	004272	2103	995728	14
47	003318	2076	997784	21	005534	2097	994466	13
48	004563	2070	997771	21	006792	2091	993208	12
49	005805	2064	997758	21	008047	2085	991953	11
50	007044	2058	997745	21	009298	2080	990702	10
51	9·008278	2052	9·997732	21	9·010546	2074	10·989454	9
52	009510	2046	997719	21	011790	2068	988210	8
53	010737	2040	997706	21	013031	2062	986969	7
54	011962	2034	997693	22	014268	2056	985732	6
55	013182	2029	997680	22	015502	2051	984498	5
56	014400	2023	997667	22	016732	2045	983268	4
57	015613	2017	997654	22	017959	2040	982041	3
58	016824	2012	997641	22	019183	2033	980817	2
59	018031	2006	997628	22	020403	2028	979597	1
60	019235	2000	997614	22	021620	2023	978380	0
	Cosine.		Sine.		Cotang.		Tang.	M.

84 Degrees.

6 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·019235	2000	9·997614	22	9·021620	2023	10·978380	60
1	020435	1995	997601	22	022834	2017	977166	59
2	021632	1989	997588	22	024044	2011	975956	58
3	022825	1984	997574	22	025251	2006	974749	57
4	024016	1978	997561	22	026455	2000	973545	56
5	025203	1973	997547	22	027655	1995	972345	55
6	026386	1967	997534	23	028852	1990	971148	54
7	027567	1962	997520	23	030046	1985	969954	53
8	028744	1957	997507	23	031237	1979	968763	52
9	029918	1951	997493	23	032425	1974	967575	51
10	031089	1947	997480	23	033609	1969	966391	50
11	9·032257	1941	9·997466	23	9·034791	1964	10·965209	49
12	033421	1936	997452	23	035969	1958	964031	48
13	034582	1930	997439	23	037144	1953	962856	47
14	035741	1925	997425	23	038316	1948	961684	46
15	036896	1920	997411	23	039485	1943	960515	45
16	038048	1915	997397	23	040651	1938	959349	44
17	039197	1910	997383	23	041813	1933	958187	43
18	040342	1905	997369	23	042973	1928	957027	42
19	041485	1899	997355	23	044130	1923	955870	41
20	042625	1894	997341	23	045284	1918	954716	40
21	9·043762	1889	9·997327	24	9·046434	1913	10·953566	39
22	044895	1884	997313	24	047582	1908	952418	38
23	046026	1879	997299	24	048727	1903	951273	37
24	047154	1875	997285	24	049869	1898	950131	36
25	048279	1870	997271	24	051008	1893	948992	35
26	049400	1865	997257	24	052144	1889	947856	34
27	050519	1860	997242	24	053277	1884	946723	33
28	051635	1855	997228	24	054407	1879	945593	32
29	052749	1850	997214	24	055535	1874	944465	31
30	053859	1845	997199	24	056659	1870	943341	30
31	9·054966	1841	9.997185	24	9·057781	1865	10·942219	29
32	056071	1836	997170	24	058900	1859	941100	28
33	057172	1831	997156	24	060016	1855	939984	27
34	058271	1827	997141	24	061130	1851	938870	26
35	059367	1822	997127	24	062240	1846	937760	25
36	060460	1817	997112	24	063348	1842	936652	24
37	061551	1813	997098	24	064453	1837	935547	23
38	062639	1808	997083	25	065556	1833	934444	22
39	063724	1804	997068	25	066655	1828	933345	21
40	064806	1799	997053	25	067752	1824	932248	20
41	9·065885	1794	9·997039	25	9.068846	1819	10·931154	19
42	066962	1790	997024	25	069938	1815	930062	18
43	068036	1786	997009	25	071027	1810	928973	17
44	069107	1781	996994	25	072113	1806	927887	16
45	070176	1777	996979	25	073197	1802	926803	15
46	071242	1772	996964	25	074278	1797	925722	14
47	072306	1768	996949	25	075356	1793	924644	13
48	073366	1763	996934	25	076432	1789	923568	12
49	074424	1759	996919	25	077505	1784	922495	11
50	075480	1755	996904	25	078576	1780	921424	10
51	9·076533	1750	9·996889	25	9·079644	1776	10·920356	9
52	077583	1746	996874	25	080710	1772	919290	8
53	078631	1742	996858	25	081773	1767	918227	7
54	079676	1738	996843	25	082833	1763	917167	6
55	080719	1733	996828	25	083891	1759	916109	5
56	081759	1729	996812	26	084947	1755	915053	4
57	082797	1725	996797	26	086000	1751	914000	3
58	083832	1721	996782	26	087050	1747	912950	2
59	084864	1717	996766	26	088098	1743	911902	1
60	085894	1713	996751	26	089144	1738	910856	0
	Cosine.		Sine.		Cotang.		Tang.	M.

83 Degrees.

7 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·085894	1713	9·996751	26	9·089144	1738	10·910856	60
1	086922	1709	996735	26	090187	1734	909813	59
2	087947	1704	996720	26	091228	1730	908772	58
3	088970	1700	996704	26	092266	1727	907734	57
4	089990	1696	996688	26	093302	1722	906698	56
5	091008	1692	996673	26	094336	1719	905664	55
6	092024	1688	996657	26	095367	1715	904633	54
7	093037	1684	996641	26	096395	1711	903605	53
8	094047	1680	996625	26	097422	1707	902578	52
9	095056	1676	996610	26	098446	1703	901554	51
10	096062	1673	996594	26	099468	1699	900532	50
11	9·097065	1668	9·996578	27	9·100487	1695	10·899513	49
12	098066	1665	996562	27	101504	1691	898496	48
13	099065	1661	996546	27	102519	1687	897481	47
14	100062	1657	996530	27	103532	1684	896468	46
15	101056	1653	996514	27	104542	1680	895458	45
16	102048	1649	996498	27	105550	1676	894450	44
17	103037	1645	996482	27	106556	1672	893444	43
18	104025	1641	996465	27	107559	1669	892441	42
19	105010	1638	996449	27	108560	1665	891440	41
20	105992	1634	996433	27	109559	1661	890441	40
21	9·106973	1630	9·996417	27	9·110556	1658	10·889444	39
22	107951	1627	996400	27	111551	1654	888449	38
23	108927	1623	996384	27	112543	1650	887457	37
24	109901	1619	996368	27	113533	1646	886467	36
25	110873	1616	996351	27	114521	1643	885479	35
26	111842	1612	996335	27	115507	1639	884493	34
27	112809	1608	996318	27	116491	1636	883509	33
28	113774	1605	996302	28	117472	1632	882528	32
29	114737	1601	996285	28	118452	1629	881548	31
30	115698	1597	996269	28	119429	1625	880571	30
31	9·116656	1594	9·996252	28	9·120404	1622	10·879596	29
32	117613	1590	996235	28	121377	1618	878623	28
33	118567	1587	996219	28	122348	1615	877652	27
34	119519	1583	996202	28	123317	1611	876683	26
35	120469	1580	996185	28	124284	1607	875716	25
36	121417	1576	996168	28	125249	1604	874751	24
37	122362	1573	996151	28	126211	1601	873789	23
38	123306	1569	996134	28	127172	1597	872828	22
39	124248	1566	996117	28	128130	1594	871870	21
40	125187	1562	996100	28	129087	1591	870913	20
41	9·126125	1559	9·996083	29	9·130041	1587	10·869959	19
42	127060	1556	996066	29	130994	1584	869006	18
43	127993	1552	996049	29	131944	1581	868056	17
44	128925	1549	996032	29	132893	1577	867107	16
45	129854	1545	996015	29	133839	1574	866161	15
46	130781	1542	995998	29	134784	1571	865216	14
47	131706	1539	995980	29	135726	1567	864274	13
48	132630	1535	995963	29	136667	1564	863333	12
49	133551	1532	995946	29	137605	1561	862395	11
50	134470	1529	995928	29	138542	1558	861458	10
51	9·135387	1525	9·995911	29	9·139476	1555	10·860524	9
52	136303	1522	995894	29	140409	1551	859591	8
53	137216	1519	995876	29	141340	1548	858660	7
54	138128	1516	995859	29	142269	1545	857731	6
55	139037	1512	995841	29	143196	1542	856804	5
56	139944	1509	995823	29	144121	1539	855879	4
57	140850	1506	995806	29	145044	1535	854956	3
58	141754	1503	995788	29	145966	1532	854034	2
59	142655	1500	995771	29	146885	1529	853115	1
60	143555	1496	995753	29	147803	1526	852197	0
	Cosine.		Sine.		Cotang.		Tang.	M.

82 Degrees.

8 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·143555	1496	9·995753	30	9·147803	1526	10·852197	60
1	144453	1493	995735	30	148718	1523	851282	59
2	145349	1490	995717	30	149632	1520	850368	58
3	146243	1487	995699	30	150544	1517	849456	57
4	147136	1484	995681	30	151454	1514	848546	56
5	148026	1481	995664	30	152363	1511	847637	55
6	148915	1478	995646	30	153269	1508	846731	54
7	149802	1475	995628	30	154174	1505	845826	53
8	150686	1472	995610	30	155077	1502	844923	52
9	151569	1469	995591	30	155978	1499	844022	51
10	152451	1466	995573	30	156877	1496	843123	50
11	9·153330	1463	9·995555	30	9·157775	1493	10·842225	49
12	154208	1460	995537	30	158671	1490	841329	48
13	155083	1457	995519	30	159565	1487	840435	47
14	155957	1454	995501	31	160457	1484	839543	46
15	156830	1451	995482	31	161347	1481	838653	45
16	157700	1448	995464	31	162236	1479	837764	44
17	158569	1445	995446	31	163123	1476	836877	43
18	159435	1442	995427	31	164008	1473	835992	42
19	160301	1439	995409	31	164892	1470	835108	41
20	161164	1436	995390	31	165774	1467	834226	40
21	9·162025	1433	9·995372	31	9·166654	1464	10·833346	39
22	162885	1430	995353	31	167532	1461	832468	38
23	163743	1427	995334	31	168409	1458	831591	37
24	164600	1424	995316	31	169284	1455	830716	36
25	165454	1422	995297	31	170157	1453	829843	35
26	166307	1419	995278	31	171029	1450	828971	34
27	167159	1416	995260	31	171899	1447	828101	33
28	168008	1413	995241	32	172767	1444	827233	32
29	168856	1410	995222	32	173634	1442	826366	31
30	169702	1407	995203	32	174499	1439	825501	30
31	9·170547	1405	9·995184	32	9·175362	1436	10·824638	29
32	171389	1402	995165	32	176224	1433	823776	28
33	172230	1399	995146	32	177084	1431	822916	27
34	173070	1396	995127	32	177942	1428	822058	26
35	173908	1394	995108	32	178799	1425	821201	25
36	174744	1391	995089	32	179655	1423	820345	24
37	175578	1388	995070	32	180508	1420	819492	23
38	176411	1386	995051	32	181360	1417	818640	22
39	177242	1383	995032	32	182211	1415	817789	21
40	178072	1380	995013	32	183059	1412	816941	20
41	9·178900	1377	9·994993	32	9·183907	1409	10·816093	19
42	179726	1374	994974	32	184752	1407	815248	18
43	180551	1372	994955	32	185597	1404	814403	17
44	181374	1369	994935	32	186439	1402	813561	16
45	182196	1366	994916	33	187280	1399	812720	15
46	183016	1364	994896	33	188120	1396	811880	14
47	183834	1361	994877	33	188958	1393	811042	13
48	184651	1359	994857	33	189794	1391	810206	12
49	185466	1356	994838	33	190629	1389	809371	11
50	186280	1353	994818	33	191462	1386	808538	10
51	9·187092	1351	9·994798	33	9·192294	1384	10·807706	9
52	187903	1348	994779	33	193124	1381	806876	8
53	188712	1346	994759	33	193953	1379	806047	7
54	189519	1343	994739	33	194780	1376	805220	6
55	190325	1341	994719	33	195606	1374	804394	5
56	191130	1338	994700	33	196430	1371	803570	4
57	191933	1336	994680	33	197253	1369	802747	3
58	192734	1333	994660	33	198074	1366	801926	2
59	193534	1330	994640	33	198894	1364	801106	1
60	194332	1328	994620	33	199713	1361	800287	0
	Cosine.		Sine.		Cotang.		Tang.	M.

81 Degrees.

9 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·194332	1328	9·994620	33	9·199713	1361	10·800287	60
1	195129	1326	994600	33	200529	1359	799471	59
2	195925	1323	994580	33	201345	1356	798655	58
3	196719	1321	994560	34	202159	1354	797841	57
4	197511	1318	994540	34	202971	1352	797029	56
5	198302	1316	994519	34	203782	1349	796218	55
6	199091	1313	994499	34	204592	1347	795408	54
7	199879	1311	994479	34	205400	1345	794600	53
8	200666	1308	994459	34	206207	1342	793793	52
9	201451	1306	994438	34	207013	1340	792987	51
10	202234	1304	994418	34	207817	1338	792183	50
11	9·203017	1301	9·994397	34	9·208619	1335	10·791381	49
12	203797	1299	994377	34	209420	1333	790580	48
13	204577	1296	994357	34	210220	1331	789780	47
14	205354	1294	994336	34	211018	1328	788982	46
15	206131	1292	994316	34	211815	1326	788185	45
16	206906	1289	994295	34	212611	1324	787389	44
17	207679	1287	994274	35	213405	1321	786595	43
18	208452	1285	994254	35	214198	1319	785802	42
19	209222	1282	994233	35	214989	1317	785011	41
20	209992	1280	994212	35	215780	1315	784220	40
21	9·210760	1278	9·994191	35	9·216568	1312	10·783432	39
22	211526	1275	994171	35	217356	1310	782644	38
23	212291	1273	994150	35	218142	1308	781858	37
24	213055	1271	994129	35	218926	1305	781074	36
25	213818	1268	994108	35	219710	1303	780290	35
26	214579	1266	994087	35	220492	1301	779508	34
27	215338	1264	994066	35	221272	1299	778728	33
28	216097	1261	994045	35	222052	1297	777948	32
29	216854	1259	994024	35	222830	1294	777170	31
30	217609	1257	994003	35	223606	1292	776394	30
31	9·218363	1255	9·993981	35	9·224382	1290	10·775618	29
32	219116	1253	993960	35	225156	1288	774844	28
33	219868	1250	993939	35	225929	1286	774071	27
34	220618	1248	993918	35	226700	1284	773300	26
35	221367	1246	993896	36	227471	1281	772529	25
36	222115	1244	993875	36	228239	1279	771761	24
37	222861	1242	993854	36	229007	1277	770993	23
38	223606	1239	993832	36	229773	1275	770227	22
39	224349	1237	993811	36	230539	1273	769461	21
40	225092	1235	993789	36	231302	1271	768698	20
41	9·225833	1233	9·993768	36	9·232065	1269	10·767935	19
42	226573	1231	993746	36	232826	1267	767174	18
43	227311	1228	993725	36	233586	1265	766414	17
44	228048	1226	993703	36	234345	1262	765655	16
45	228784	1224	993681	36	235103	1260	764897	15
46	229518	1222	993660	36	235859	1258	764141	14
47	230252	1220	993638	36	236614	1256	763386	13
48	230984	1218	993616	36	237368	1254	762632	12
49	231714	1216	993594	37	238120	1252	761880	11
50	232444	1214	993572	37	238872	1250	761128	10
51	9·233172	1212	9·993550	37	9·239622	1248	10·760378	9
52	233899	1209	993528	37	240371	1246	759629	8
53	234625	1207	993506	37	241118	1244	758882	7
54	235349	1205	993484	37	241865	1242	758135	6
55	236073	1203	993462	37	242610	1240	757390	5
56	236795	1201	993440	37	243354	1238	756646	4
57	237515	1199	993418	37	244097	1236	755903	3
58	238235	1197	993396	37	244839	1234	755161	2
59	238953	1195	993374	37	245579	1232	754421	1
60	239670	1193	993351	37	246319	1230	753681	0
	Cosine.		Sine.		Cotang.		Tang.	M.

80 Degrees.

10 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·239670	1193	9·993351	37	9·246319	1230	10·753681	60
1	240386	1191	993329	37	247057	1228	752943	59
2	241101	1189	993307	37	247794	1226	752206	58
3	241814	1187	993285	37	248530	1224	751470	57
4	242526	1185	993262	37	249264	1222	750736	56
5	243237	1183	993240	37	249998	1220	750002	55
6	243947	1181	993217	38	250730	1218	749270	54
7	244656	1179	993195	38	251461	1217	748539	53
8	245363	1177	993172	38	252191	1215	747809	52
9	246069	1175	993149	38	252920	1213	747080	51
10	246775	1173	993127	38	253648	1211	746352	50
11	9·247478	1171	9·993104	38	9·254374	1209	10·745626	49
12	248181	1169	993081	38	255100	1207	744900	48
13	248883	1167	993059	38	255824	1205	744176	47
14	249583	1165	993036	38	256547	1203	743453	46
15	250282	1163	993013	38	257269	1201	742731	45
16	250980	1161	992990	38	257990	1200	742010	44
17	251677	1159	992967	38	258710	1198	741290	43
18	252373	1158	992944	38	259429	1196	740571	42
19	253067	1156	992921	38	260146	1194	739854	41
20	253761	1154	992898	38	260863	1192	739137	40
21	9·254453	1152	9·992875	38	9·261578	1190	10·738422	39
22	255144	1150	992852	38	262292	1189	737708	38
23	255834	1148	992829	39	263005	1187	736995	37
24	256523	1146	992806	39	263717	1185	736283	36
25	257211	1144	992783	39	264428	1183	735572	35
26	257898	1142	992759	39	265138	1181	734862	34
27	258583	1141	992736	39	265847	1179	734153	33
28	259268	1139	992713	39	266555	1178	733445	32
29	259951	1137	992690	39	267261	1176	732739	31
30	260633	1135	992666	39	267967	1174	732033	30
31	9·261314	1133	9·992643	39	9·268671	1172	10·731329	29
32	261994	1131	992619	39	269375	1170	730625	28
33	262673	1130	992596	39	270077	1169	729923	27
34	263351	1128	992572	39	270779	1167	729221	26
35	264027	1126	992549	39	271479	1165	728521	25
36	264703	1124	992525	39	272178	1164	727822	24
37	265377	1122	992501	39	272876	1162	727124	23
38	266051	1120	992478	40	273573	1160	726427	22
39	266723	1119	992454	40	274269	1158	725731	21
40	267395	1117	992430	40	274964	1157	725036	20
41	9·268065	1115	9·992406	40	9·275658	1155	10·724342	19
42	268734	1113	992382	40	276351	1153	723649	18
43	269402	1111	992359	40	277043	1151	722957	17
44	270069	1110	992335	40	277734	1150	722266	16
45	270735	1108	992311	40	278424	1148	721576	15
46	271400	1106	992287	40	279113	1147	720887	14
47	272064	1105	992263	40	279801	1145	720199	13
48	272726	1103	992239	40	280488	1143	719512	12
49	273388	1101	992214	40	281174	1141	718826	11
50	274049	1099	992190	40	281858	1140	718142	10
51	9·274708	1098	9·992166	40	9·282542	1138	10·717458	9
52	275367	1096	992142	40	283225	1136	716775	8
53	276024	1094	992117	41	283907	1135	716093	7
54	276681	1092	992093	41	284588	1133	715412	6
55	277337	1091	992069	41	285268	1131	714732	5
56	277991	1089	992044	41	285947	1130	714053	4
57	278644	1087	992020	41	286624	1128	713376	3
58	279297	1086	991996	41	287301	1126	712699	2
59	279948	1084	991971	41	287977	1125	712023	1
60	280599	1082	991947	41	288652	1123	711348	0
	Cosine.		Sine.		Cotang.		Tang.	M.

79 Degrees.

11 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·280599	1082	9·991947	41	9·288652	1123	10·711348	60
1	281248	1081	991922	41	289326	1122	710674	59
2	281897	1079	991897	41	289999	1120	710001	58
3	282544	1077	991873	41	290671	1118	709329	57
4	283190	1076	991848	41	291342	1117	708658	56
5	283836	1074	991823	41	292013	1115	707987	55
6	284480	1072	991799	41	292682	1114	707318	54
7	285124	1071	991774	42	293350	1112	706650	53
8	285766	1069	991749	42	294017	1111	705983	52
9	286408	1067	991724	42	294684	1109	705316	51
10	287048	1066	991699	42	295349	1107	704651	50
11	9·287687	1064	9·991674	42	9·296013	1106	10·703987	49
12	288326	1063	991649	42	296677	1104	703323	48
13	288964	1061	991624	42	297339	1103	702661	47
14	289600	1059	991599	42	298001	1101	701999	46
15	290236	1058	991574	42	298662	1100	701338	45
16	290870	1056	991549	42	299322	1098	700678	44
17	291504	1054	991524	42	299980	1096	700020	43
18	292137	1053	991498	42	300638	1095	699362	42
19	292768	1051	991473	42	301295	1093	698705	41
20	293399	1050	991448	42	301951	1092	698049	40
21	9·294029	1048	9·991422	42	9·302607	1090	10·697393	39
22	294658	1046	991397	42	303261	1089	696739	38
23	295286	1045	991372	43	303914	1087	696086	37
24	295913	1043	991346	43	304567	1086	695433	36
25	296539	1042	991321	43	305218	1084	694782	35
26	297164	1040	991295	43	305869	1083	694131	34
27	297788	1039	991270	43	306519	1081	693481	33
28	298412	1037	991244	43	307168	1080	692832	32
29	299034	1036	991218	43	307815	1078	692185	31
30	299655	1034	991193	43	308463	1077	691537	30
31	9·300276	1032	9·991167	43	9·309109	1075	10·690891	29
32	300895	1031	991141	43	309754	1074	690246	28
33	301514	1029	991115	43	310398	1073	689602	27
34	302132	1028	991090	43	311042	1071	688958	26
35	302748	1026	991064	43	311685	1070	688315	25
36	303364	1025	991038	43	312327	1068	687673	24
37	303979	1023	991012	43	312967	1067	687033	23
38	304593	1022	990986	43	313608	1065	686392	22
39	305207	1020	990960	43	314247	1064	685753	21
40	305819	1019	990934	44	314885	1062	685115	20
41	9·306430	1017	9·990908	44	9·315523	1061	10·684477	19
42	307041	1016	990882	44	316159	1060	683841	18
43	307650	1014	990855	44	316795	1058	683205	17
44	308259	1013	990829	44	317430	1057	682570	16
45	308867	1011	990803	44	318064	1055	681936	15
46	309474	1010	990777	44	318697	1054	681303	14
47	310080	1008	990750	44	319329	1053	680671	13
48	310685	1007	990724	44	319961	1051	680039	12
49	311289	1005	990697	44	320592	1050	679408	11
50	311893	1004	990671	44	321222	1048	678778	10
51	9·312495	1003	9·990644	44	9·321851	1047	10·678149	9
52	313097	1001	990618	44	322479	1045	677521	8
53	313698	1000	990591	44	323106	1044	676894	7
54	314297	998	990565	44	323733	1043	676267	6
55	314897	997	990538	44	324358	1041	675642	5
56	315495	996	990511	45	324983	1040	675017	4
57	316092	994	990485	45	325607	1039	674393	3
58	316689	993	990458	45	326231	1037	673769	2
59	317284	991	990431	45	326853	1036	673147	1
60	317879	990	990404	45	327475	1035	672525	0
	Cosine.		Sine.		Cotang.		Tang.	M.

78 Degrees.

12 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·317879	990	9·990404	45	9·327474	1035	10·672526	60
1	318473	988	990378	45	328095	1033	671905	59
2	319066	987	990351	45	328715	1032	671285	58
3	319658	986	990324	45	329334	1030	670666	57
4	320249	984	990297	45	329953	1029	670047	56
5	320840	983	990270	45	330570	1028	669430	55
6	321430	982	990243	45	331187	1026	668813	54
7	322019	980	990215	45	331803	1025	668197	53
8	322607	979	990188	45	332418	1024	667582	52
9	323194	977	990161	45	333033	1023	666967	51
10	323780	976	990134	45	333646	1021	666354	50
11	9·324366	975	9·990107	46	9·334259	1020	10·665741	49
12	324950	973	990079	46	334871	1019	665129	48
13	325534	972	990052	46	335482	1017	664518	47
14	326117	970	990025	46	336093	1016	663907	46
15	326700	969	989997	46	336702	1015	663298	45
16	327281	968	989970	46	337311	1013	662689	44
17	327862	966	989942	46	337919	1012	662081	43
18	328442	965	989915	46	338527	1011	661473	42
19	329021	964	989887	46	339133	1010	660867	41
20	329599	962	989860	46	339739	1008	660261	40
21	9·330176	961	9·989832	46	9·340344	1007	10·659656	39
22	330753	960	989804	46	340948	1006	659052	38
23	331329	958	989777	46	341552	1004	658448	37
24	331903	957	989749	47	342155	1003	657845	36
25	332478	956	989721	47	342757	1002	657243	35
26	333051	954	989693	47	343358	1000	656642	34
27	333624	953	989665	47	343958	999	656042	33
28	334195	952	989637	47	344558	998	655442	32
29	334766	950	989609	47	345157	997	654843	31
30	335337	949	989582	47	345755	996	654245	30
31	9·335906	948	9·989553	47	9·346353	994	10·653647	29
32	336475	946	989525	47	346949	993	653051	28
33	337043	945	989497	47	347545	992	652455	27
34	337610	944	989469	47	348141	991	651859	26
35	338176	943	989441	47	348735	990	651265	25
36	338742	941	989413	47	349329	988	650671	24
37	339306	940	989384	47	349922	987	650078	23
38	339871	939	989356	47	350514	986	649486	22
39	340434	937	989328	47	351106	985	648894	21
40	340996	936	989300	47	351697	983	648303	20
41	9·341558	935	9·989271	47	9·352287	982	10·647713	19
42	342119	934	989243	47	352876	981	647124	18
43	342679	932	989214	47	353465	980	646535	17
44	343239	931	989186	47	354053	979	645947	16
45	343797	930	989157	47	354640	977	645360	15
46	344355	929	989128	48	355227	976	644773	14
47	344912	927	989100	48	355813	975	644187	13
48	345469	926	989071	48	356398	974	643602	12
49	346024	925	989042	48	356982	973	643018	11
50	346579	924	989014	48	357566	971	642434	10
51	9·347134	922	9·988985	48	9·358149	970	10·641851	9
52	347687	921	988956	48	358731	969	641269	8
53	348240	920	988927	48	359313	968	640687	7
54	348792	919	988898	48	359893	967	640107	6
55	349343	917	988869	48	360474	966	639526	5
56	349893	916	988840	48	361053	965	638947	4
57	350443	915	988811	49	361632	963	638368	3
58	350992	914	988782	49	362210	962	637790	2
59	351540	913	988753	49	362787	961	637213	1
60	352088	911	988724	49	363364	960	636636	0
	Cosine.		Sine.		Cotang.		Tang.	M.

77 Degrees.

13 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·352088	911	9·988724	49	9·363364	960	10·636636	60
1	352635	910	988695	49	363940	959	636060	59
2	353181	909	988666	49	364515	958	635485	58
3	353726	908	988636	49	365090	957	634910	57
4	354271	907	988607	49	365664	955	634336	56
5	354815	905	988578	49	366237	954	633763	55
6	355358	904	988548	49	366810	953	633190	54
7	355901	903	988519	49	367382	952	632618	53
8	356443	902	988489	49	367953	951	632047	52
9	356984	901	988460	49	368524	950	631476	51
10	357524	899	988430	49	369094	949	630906	50
11	9·358064	898	9·988401	49	9·369663	948	10·630337	49
12	358603	897	988371	49	370232	946	629768	48
13	359141	896	988342	49	370799	945	629201	47
14	359678	895	988312	50	371367	944	628633	46
15	360215	893	988282	50	371933	943	628067	45
16	360752	892	988252	50	372499	942	627501	44
17	361287	891	988223	50	373064	941	626936	43
18	361822	890	988193	50	373629	940	626371	42
19	362356	889	988163	50	374193	939	625807	41
20	362889	888	988133	50	374756	938	625244	40
21	9·363422	887	9·988103	50	9·375319	937	10·624681	39
22	363954	885	988073	50	375881	935	624119	38
23	364485	884	988043	50	376442	934	623558	37
24	365016	883	988013	50	377003	933	622997	36
25	365546	882	987983	50	377563	932	622437	35
26	366075	881	987953	50	378122	931	621878	34
27	366604	880	987922	50	378681	930	621319	33
28	367131	879	987892	50	379239	929	620761	32
29	367659	877	987862	50	379797	928	620203	31
30	368185	876	987832	51	380354	927	619646	30
31	9·368711	875	9·987801	51	9·380910	926	10·619090	29
32	369236	874	987771	51	381466	925	618534	28
33	369761	873	987740	51	382020	924	617980	27
34	370285	872	987710	51	382575	923	617425	26
35	370808	871	987679	51	383129	922	616871	25
36	371330	870	987649	51	383682	921	616318	24
37	371852	869	987618	51	384234	920	615766	23
38	372373	867	987588	51	384786	919	615214	22
39	372894	866	987557	51	385337	918	614663	21
40	373414	865	987526	51	385888	917	614112	20
41	9·373933	864	9·987496	51	9·386438	915	10·613562	19
42	374452	863	987465	51	386987	914	613013	18
43	374970	862	987434	51	387536	913	612464	17
44	375487	861	987403	52	388084	912	611916	16
45	376003	860	987372	52	388631	911	611369	15
46	376519	859	987341	52	389178	910	610822	14
47	377035	858	987310	52	389724	909	610276	13
48	377549	857	987279	52	390270	908	609730	12
49	378063	856	987248	52	390815	907	609185	11
50	378577	854	987217	52	391360	906	608640	10
51	9·379089	853	9·987186	52	9·391903	905	10·608097	9
52	379601	852	987155	52	392447	904	607553	8
53	380113	851	987124	52	392989	903	607011	7
54	380624	850	987092	52	393531	902	606469	6
55	381134	849	987061	52	394073	901	605927	5
56	381643	848	987030	52	394614	900	605386	4
57	382152	847	986998	52	395154	899	604846	3
58	382661	846	986967	52	395694	898	604306	2
59	383168	845	986936	52	396233	897	603767	1
60	383675	844	986004	52	396771	896	603229	0
	Cosine.		Sine.		Cotang.		Tang.	M.

76 Degrees.

14 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·383675	844	9·986904	52	9·396771	896	10·603229	60
1	384182	843	986873	53	397309	896	602691	59
2	384687	842	986841	53	397846	895	602154	58
3	385192	841	986809	53	398383	894	601617	57
4	385697	840	986778	53	398919	893	601081	56
5	386201	839	986746	53	399455	892	600545	55
6	386704	838	986714	53	399990	891	600010	54
7	387207	837	986683	53	400524	890	599476	53
8	387709	836	986651	53	401058	889	598942	52
9	388210	835	986619	53	401591	888	598409	51
10	388711	834	986587	53	402124	887	597876	50
11	9·389211	833	9·986555	53	9·402656	886	10·597344	49
12	389711	832	986523	53	403187	885	596813	48
13	390210	831	986491	53	403718	884	596282	47
14	390708	830	986459	53	404249	883	595751	46
15	391206	828	986427	53	404778	882	595222	45
16	391703	827	986395	53	405308	881	594692	44
17	392199	826	986363	54	405836	880	594164	43
18	392695	825	986331	54	406364	879	593636	42
19	393191	824	986299	54	406892	878	593108	41
20	393685	823	986266	54	407419	877	592581	40
21	9·394179	822	9·986234	54	9·407945	876	10·592055	39
22	394673	821	986202	54	408471	875	591529	38
23	395166	820	986169	54	408997	874	591003	37
24	395658	819	986137	54	409521	874	590479	36
25	396150	818	986104	54	410045	873	589955	35
26	396641	817	986072	54	410569	872	589431	34
27	397132	817	986039	54	411092	871	588908	33
28	397621	816	986007	54	411615	870	588385	32
29	398111	815	985974	54	412137	869	587863	31
30	398600	814	985942	54	412658	868	587342	30
31	9·399088	813	9.985909	55	9·413179	867	10·586821	29
32	399575	812	985876	55	413699	866	586301	28
33	400062	811	985843	55	414219	865	585781	27
34	400549	810	985811	55	414738	864	585262	26
35	401035	809	985778	55	415257	864	584743	25
36	401520	808	985745	55	415775	863	584225	24
37	402005	807	985712	55	416293	862	583707	23
38	402489	806	985679	55	416810	861	583190	22
39	402972	805	985646	55	417326	860	582674	21
40	403455	804	985613	55	417842	859	582158	20
41	9·403938	803	9·985580	55	9·418358	858	10·581642	19
42	404420	802	985547	55	418873	857	581127	18
43	404901	801	985514	55	419387	856	580613	17
44	405382	800	985480	55	419901	855	580099	16
45	405862	799	985447	55	420415	855	579585	15
46	406341	798	985414	56	420927	854	579073	14
47	406820	797	985380	56	421440	853	578560	13
48	407299	796	985347	56	421952	852	578048	12
49	407777	795	985314	56	422463	851	577537	11
50	408254	794	985280	56	422974	850	577026	10
51	9·408731	794	9·985247	56	9·423484	849	10·576516	9
52	409207	793	985213	56	423993	848	576007	8
53	409682	792	985180	56	424503	848	575497	7
54	410157	791	985146	56	425011	847	574989	6
55	410632	790	985113	56	425519	846	574481	5
56	411106	789	985079	56	426027	845	573973	4
57	411579	788	985045	56	426534	844	573466	3
58	412052	787	985011	56	427041	843	572959	2
59	412524	786	984978	56	427547	843	572453	1
60	412996	785	984944	56	428052	842	571948	0
	Cosine.		Sine.		Cotang.		Tang.	M.

75 Degrees.

15 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·412996	785	9·984944	57	9·428052	842	10·571948	60
1	413467	784	984910	57	428557	841	571443	59
2	413938	783	984876	57	429062	840	570938	58
3	414408	783	984842	57	429566	839	570434	57
4	414878	782	984808	57	430070	838	569930	56
5	415347	781	984774	57	430573	838	569427	55
6	415815	780	984740	57	431075	837	568925	54
7	416283	779	984706	57	431577	836	568423	53
8	416751	778	984672	57	432079	835	567921	52
9	417217	777	984637	57	432580	834	567420	51
10	417684	776	984603	57	433080	833	566920	50
11	9·418150	775	9·984569	57	9·433580	832	10·566420	49
12	418615	774	984535	57	434080	832	565920	48
13	419079	773	984500	57	434579	831	565421	47
14	419544	773	984466	57	435078	830	564922	46
15	420007	772	984432	58	435576	829	564424	45
16	420470	771	984397	58	436073	828	563927	44
17	420933	770	984363	58	436570	828	563430	43
18	421395	769	984328	58	437067	827	562933	42
19	421857	768	984294	58	437563	826	562437	41
20	422318	767	984259	58	438059	825	561941	40
21	9·422778	767	9·984224	58	9·438554	824	10·561446	39
22	423238	766	984190	58	439048	823	560952	38
23	423697	765	984155	58	439543	823	560457	37
24	424156	764	984120	58	440036	822	559964	36
25	424615	763	984085	58	440529	821	559471	35
26	425073	762	984050	58	441022	820	558978	34
27	425530	761	984015	58	441514	819	558486	33
28	425987	760	983981	58	442006	819	557994	32
29	426443	760	983946	58	442497	818	557503	31
30	426899	759	983911	58	442988	817	557012	30
31	9·427354	758	9·983875	58	9·443479	816	10·556521	29
32	427809	757	983840	59	443968	816	556032	28
33	428263	756	983805	59	444458	815	555542	27
34	428717	755	983770	59	444947	814	555053	26
35	429170	754	983735	59	445435	813	554565	25
36	429623	753	983700	59	445923	812	554077	24
37	430075	752	983664	59	446411	812	553589	23
38	430527	752	983629	59	446898	811	553102	22
39	430978	751	983594	59	447384	810	552616	21
40	431429	750	983558	59	447870	809	552130	20
41	9·431879	749	9·983523	59	9·448356	809	10·551644	19
42	432329	749	983487	59	448841	808	551159	18
43	432778	748	983452	59	449326	807	550674	17
44	433226	747	983416	59	449810	806	550190	16
45	433675	746	983381	59	450294	806	549706	15
46	434122	745	983345	59	450777	805	549223	14
47	434569	744	983309	59	451260	804	548740	13
48	435016	744	983273	60	451743	803	548257	12
49	435462	743	983238	60	452225	802	547775	11
50	435908	742	983202	60	452706	802	547294	10
51	9·436353	741	9·983166	60	9·453187	801	10·546813	9
52	436798	740	983130	60	453668	800	546332	8
53	437242	740	983094	60	454148	799	545852	7
54	437686	739	983058	60	454628	799	545372	6
55	438129	738	983022	60	455107	798	544893	5
56	438572	737	982986	60	455586	797	544414	4
57	439014	736	982950	60	456064	796	543936	3
58	439456	736	982914	60	456542	796	543458	2
59	439897	735	982878	60	457019	795	542981	1
60	440338	734	982842	60	457496	794	542504	0
	Cosine.		Sine.		Cotang.		Tang.	M.

74 Degrees.

16 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·440338	734	9·982842	60	9·457496	794	10·542504	60
1	440778	733	982805	60	457973	793	542027	59
2	441218	732	982769	61	458449	793	541551	58
3	441658	731	982733	61	458925	792	541075	57
4	442096	731	982696	61	459400	791	540600	56
5	442535	730	982660	61	459875	790	540125	55
6	442973	729	982624	61	460349	790	539651	54
7	443410	728	982587	61	460823	789	539177	53
8	443847	727	982551	61	461297	788	538703	52
9	444284	727	982514	61	461770	788	538230	51
10	444720	726	982477	61	462242	787	537758	50
11	9·445155	725	9·982441	61	9·462714	786	10·537286	49
12	445590	724	982404	61	463186	785	536814	48
13	446025	723	982367	61	463658	785	536342	47
14	446459	723	982331	61	464129	784	535871	46
15	446893	722	982294	61	464599	783	535401	45
16	447326	721	982257	61	465069	783	534931	44
17	447759	720	982220	62	465539	782	534461	43
18	448191	720	982183	62	466008	781	533992	42
19	448623	719	982146	62	466476	780	533524	41
20	449054	718	982109	62	466945	780	533055	40
21	9·449485	717	9·982072	62	9·467413	779	10·532587	39
22	449915	716	982035	62	467880	778	532120	38
23	450345	716	981998	62	468347	778	531653	37
24	450775	715	981961	62	468814	777	531186	36
25	451204	714	981924	62	469280	776	530720	35
26	451632	713	981886	62	469746	775	530254	34
27	452060	713	981849	62	470211	775	529789	33
28	452488	712	981812	62	470676	774	529324	32
29	452915	711	981774	62	471141	773	528859	31
30	453342	710	981737	62	471605	773	528395	30
31	9·453768	710	9·981699	63	9·472068	772	10·527932	29
32	454194	709	981662	63	472532	771	527468	28
33	454619	708	981625	63	472995	771	527005	27
34	455044	707	981587	63	473457	770	526543	26
35	455469	707	981549	63	473919	769	526081	25
36	455893	706	981512	63	474381	769	525619	24
37	456316	705	981474	63	474842	768	525158	23
38	456739	704	981436	63	475303	767	524697	22
39	457162	704	981399	63	475763	767	524237	21
40	457584	703	981361	63	476223	766	523777	20
41	9·458006	702	9·981323	63	9·476683	765	10·523317	19
42	458427	701	981285	63	477142	765	522858	18
43	458848	701	981247	63	477601	764	522399	17
44	459268	700	981209	63	478059	763	521941	16
45	459688	699	981171	63	478517	763	521483	15
46	460108	698	981133	64	478975	762	521025	14
47	460527	698	981095	64	479432	761	520568	13
48	460946	697	981057	64	479889	761	520111	12
49	461364	696	981019	64	480345	760	519655	11
50	461782	695	980981	64	480801	759	519199	10
51	9·462199	695	9.980942	64	9·481257	759	10·518743	9
52	462616	694	980904	64	481712	758	518288	8
53	463032	693	980866	64	482167	757	517833	7
54	463448	693	980827	64	482621	757	517379	6
55	463864	692	980789	64	483075	756	516925	5
56	464279	691	980750	64	483529	755	516471	4
57	464694	690	980712	64	483982	755	516018	3
58	465108	690	980673	64	484435	754	515565	2
59	465522	689	980635	64	484887	753	515113	1
60	465935	688	980596	64	485339	753	514661	0
	Cosine.		Sine.		Cotang.		Tang.	M.

73 Degrees.

17 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·465935	688	9·980596	64	9·485339	755	10·514661	60
1	466348	688	980558	64	485791	752	514209	59
2	466761	687	980519	65	486242	751	513758	58
3	467173	686	980480	65	486693	751	513307	57
4	467585	685	980442	65	487143	750	512857	56
5	467996	685	980403	65	487593	749	512407	55
6	468407	684	980364	65	488043	749	511957	54
7	468817	683	980325	65	488492	748	511508	53
8	469227	683	980286	65	488941	747	511059	52
9	469637	682	980247	65	489390	747	510610	51
10	470046	681	980208	65	489838	746	510162	50
11	9·470455	680	9·980169	65	9·490286	746	10·509714	49
12	470863	680	980130	65	490733	745	509267	48
13	471271	679	980091	65	491180	744	508820	47
14	471679	678	980052	65	491627	744	508373	46
15	472086	678	980012	65	492073	743	507927	45
16	472492	677	979973	65	492519	743	507481	44
17	472898	676	979934	66	492965	742	507035	43
18	473304	676	979895	66	493410	741	506590	42
19	473710	675	979855	66	493854	740	506146	41
20	474115	674	979816	66	494299	740	505701	40
21	9·474519	674	9·979776	66	9·494743	740	10·505257	39
22	474923	673	979737	66	495186	739	504814	38
23	475327	672	979697	66	495630	738	504370	37
24	475730	672	979658	66	496073	737	503927	36
25	476133	671	979618	66	496515	737	503485	35
26	476536	670	679579	66	496957	736	503043	34
27	476938	669	979539	66	497399	736	502601	33
28	477340	669	979499	66	497841	735	502159	32
29	477741	668	979459	66	498282	734	501718	31
30	478142	667	979420	66	498722	734	501278	30
31	9·478542	667	9·979380	66	9·499163	733	10·500837	29
32	478942	666	979340	66	499603	733	500397	28
33	479342	665	979300	67	500042	732	499958	27
34	479741	665	979260	67	500481	731	499519	26
35	480140	664	979220	67	500920	731	499080	25
36	480539	663	979180	67	501359	730	498641	24
37	480937	663	979140	67	501797	730	498203	23
38	481334	662	979100	67	502235	729	497765	22
39	481731	661	979059	67	502672	728	497328	21
40	482128	661	979019	67	503109	728	496891	20
41	9·482525	660	9·978979	67	9·503546	727	10·496454	19
42	482921	659	978939	67	503982	727	496018	18
43	483316	659	978898	67	504418	726	495582	17
44	483712	658	978858	67	504854	725	495146	16
45	484107	657	978817	67	505289	725	494711	15
46	484501	657	978777	67	505724	724	494276	14
47	484895	656	978736	67	506159	724	493841	13
48	485289	655	978696	68	506593	723	493407	12
49	485682	655	978655	68	507027	722	492973	11
50	486075	654	978615	68	507460	722	492540	10
51	9·486467	653	9·978574	68	9.507893	721	10·492107	9
52	486860	653	978533	68	508326	721	491674	8
53	487251	652	978493	68	508759	720	491241	7
54	487643	651	978452	68	509191	719	490809	6
55	488034	651	978411	68	509622	719	490378	5
56	488424	650	978370	68	510054	718	489946	4
57	488814	650	978329	68	510485	718	489515	3
58	489204	649	978288	68	510916	717	489084	2
59	489593	648	978247	68	511346	716	488654	1
60	489982	648	978206	68	511776	716	488224	0
	Cosine.		Sine.		Cotang.		Tang.	M.

72 Degrees.

18 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·489982	648	9·978206	68	9·511776	716	10·488224	60
1	490371	648	978165	68	512206	716	487794	59
2	490759	647	978124	68	512635	715	487365	58
3	491147	646	978083	69	513064	714	486936	57
4	491535	646	978042	69	513493	714	486507	56
5	491922	645	978001	69	513921	713	486079	55
6	492308	644	977959	69	514349	713	485651	54
7	492695	644	977918	69	514777	712	485223	53
8	493081	643	977877	69	515204	712	484796	52
9	493466	642	977835	69	515631	711	484369	51
10	493851	642	977794	69	516057	710	483943	50
11	9·494236	641	9·977752	69	9·516484	710	10·483516	49
12	494621	641	977711	69	516910	709	483090	48
13	495005	640	977669	69	517335	709	482665	47
14	495388	639	977628	69	517761	708	482239	46
15	495772	639	977586	69	518185	708	481815	45
16	496154	638	977544	70	518510	707	481390	44
17	496537	637	977503	70	519034	706	480966	43
18	496919	637	977461	70	519458	706	480542	42
19	497301	636	977419	70	519882	705	480118	41
20	497682	636	977377	70	520305	705	479695	40
21	9·498064	635	9·977335	70	9·520728	704	10·479272	39
22	498444	634	977293	70	521151	703	478849	38
23	498825	634	977251	70	521571	703	478427	37
24	499204	633	977209	70	521995	703	478005	36
25	499584	632	977167	70	522417	702	477583	35
26	499963	632	977125	70	522838	702	477162	34
27	500342	631	977083	70	523259	701	476741	33
28	500721	631	977041	70	523680	701	476320	32
29	501099	630	976999	70	524100	700	475900	31
30	501476	629	976957	70	524520	699	475480	30
31	9·501854	629	9·976914	70	9·524939	699	10·475061	29
32	502231	628	976872	71	525359	698	474641	28
33	502607	628	976830	71	525778	698	474222	27
34	502984	627	976787	71	526197	697	473803	26
35	503360	626	976745	71	526615	697	473385	25
36	503735	626	976702	71	527033	696	472967	24
37	504110	625	976660	71	527451	696	472549	23
38	504485	625	976617	71	527868	695	472132	22
39	504860	624	976574	71	528285	695	471715	21
40	505234	623	976532	71	528702	694	471298	20
41	9·505608	623	9·976489	71	9·529119	693	10·470881	19
42	505981	622	976446	71	529535	693	470465	18
43	506354	622	976404	71	529950	693	470050	17
44	506727	621	976361	71	530366	692	469634	16
45	507099	620	976318	71	530781	691	469219	15
46	507471	620	976275	71	531196	691	468804	14
47	507843	619	976232	72	531611	690	468389	13
48	508214	619	976189	72	532025	690	467975	12
49	508585	618	976146	72	532439	689	467561	11
50	508956	618	976103	72	532853	689	467147	10
51	9·509326	617	9·976060	72	9·533266	688	10·466734	9
52	509696	616	976017	72	533679	688	466321	8
53	510065	616	975974	72	534092	687	465908	7
54	510434	615	975930	72	534504	687	465496	6
55	510803	615	975887	72	534916	686	465084	5
56	511172	614	975844	72	535328	686	464672	4
57	511540	613	975800	72	535739	685	464261	3
58	511907	613	975757	72	536150	685	463850	2
59	512275	612	975714	72	536561	684	463439	1
60	512642	612	975670	72	536972	684	463028	0
	Cosine.		Sine.		Cotang.		Tang.	M.

71 Degrees.

19 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·512642	612	9·975670	73	9·536972	684	10·463028	60
1	513009	611	975627	73	537382	683	462618	59
2	513375	611	975583	73	537792	683	462208	58
3	513741	610	975539	73	538202	682	461798	57
4	514107	609	975496	73	538611	682	461389	56
5	514472	609	975452	73	539020	681	460980	55
6	514837	608	975408	73	539429	681	460571	54
7	515202	608	975365	73	539837	680	460163	53
8	515566	607	975321	73	540245	680	459755	52
9	515930	607	975277	73	540653	679	459347	51
10	516294	606	975233	73	541061	679	458939	50
11	9·516657	605	9·975189	73	9·541468	678	10·458532	49
12	517020	605	975145	73	541875	678	458125	48
13	517382	604	975101	73	542281	677	457719	47
14	517745	604	975057	73	542688	677	457312	46
15	518107	603	975013	73	543094	676	456906	45
16	518468	603	974969	74	543499	676	456501	44
17	518829	602	974925	74	543905	675	456095	43
18	519190	601	974880	74	544310	675	455690	42
19	519551	601	974836	74	544715	674	455285	41
20	519911	600	974792	74	545119	674	454881	40
21	9·520271	600	9·974748	74	9·545524	673	10·454476	39
22	520631	599	974703	74	545928	673	454072	38
23	520990	599	974659	74	546331	672	453669	37
24	521349	598	974614	74	546735	672	453265	36
25	521707	598	974570	74	547138	671	452862	35
26	522066	597	974525	74	547540	671	452460	34
27	522424	596	974481	74	547943	670	452057	33
28	522781	596	974436	74	548345	670	451655	32
29	523138	595	974391	74	548747	669	451253	31
30	523495	595	974347	75	549149	669	450851	30
31	9·523852	594	9·974302	75	9·549550	668	10·450450	29
32	524208	594	974257	75	549951	668	450049	28
33	524564	593	974212	75	550352	667	449648	27
34	524920	593	974167	75	550752	667	449248	26
35	525275	592	974122	75	551152	666	448848	25
36	525630	591	974077	75	551552	666	448448	24
37	525984	591	974032	75	551952	665	448048	23
38	526339	590	973987	75	552351	665	447649	22
39	526693	590	973942	75	552750	665	447250	21
40	527046	589	973897	75	553149	664	446851	20
41	9·527400	589	9·973852	75	9·553548	664	10·446452	19
42	527753	588	973807	75	553946	663	446054	18
43	528105	588	973761	75	554344	663	445656	17
44	528458	587	973716	76	554741	662	445259	16
45	528810	587	973671	76	555139	662	444861	15
46	529161	586	973625	76	555536	661	444464	14
47	529513	586	973580	76	555933	661	444067	13
48	529864	585	973535	76	556329	660	443671	12
49	530215	585	973489	76	556725	660	443275	11
50	530565	584	973444	76	557121	659	442879	10
51	9·530915	584	9·973398	76	9·557517	659	10·442483	9
52	531265	583	973352	76	557913	659	442087	8
53	531614	582	973307	76	558308	658	441692	7
54	531963	582	973261	76	558702	658	441298	6
55	532312	581	973215	76	559097	657	440903	5
56	532661	581	973169	76	559491	657	440509	4
57	533009	580	973124	76	559885	656	440115	3
58	533357	580	973078	76	560279	656	439721	2
59	533704	579	973032	77	560673	655	439327	1
60	534052	578	972986	77	561066	655	438934	0
	Cosine.		Sine.		Cotang.		Tang.	M.

70 Degrees.

20 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·534052	578	9·972986	77	9·561066	655	10·438934	60
1	534399	577	972940	77	561459	654	438541	59
2	534745	577	972894	77	561851	654	438149	58
3	535092	577	972848	77	562244	653	437756	57
4	535438	576	972802	77	562636	653	437364	56
5	535783	576	972755	77	563028	653	436972	55
6	536129	575	972709	77	563419	652	436581	54
7	536474	574	972663	77	563811	652	436189	53
8	536818	574	972617	77	564202	651	435798	52
9	537163	573	972570	77	564592	651	435408	51
10	537507	573	972524	77	564983	650	435017	50
11	9·537851	572	9·972478	77	9·565373	650	10·434627	49
12	538194	572	972431	78	565763	649	434237	48
13	538538	571	972385	78	566153	649	433847	47
14	538880	571	972338	78	566542	649	433458	46
15	539223	570	972291	78	566932	648	433068	45
16	539565	570	972245	78	567320	648	432680	44
17	539907	569	972198	78	567709	647	432291	43
18	540249	569	972151	78	568098	647	431902	42
19	540590	568	972105	78	568486	646	431514	41
20	540931	568	972058	78	568873	646	431127	40
21	9·541272	567	9·972011	78	9·569261	645	10·430739	39
22	541613	567	971964	78	569648	645	430352	38
23	541953	566	971917	78	570035	645	429965	37
24	542293	566	971870	78	570422	644	429578	36
25	542632	565	971823	78	570809	644	429191	35
26	542971	565	971776	78	571195	643	428805	34
27	543310	564	971729	79	571581	643	428419	33
28	543649	564	971682	79	571967	642	428033	32
29	543987	563	971635	79	572352	642	427648	31
30	544325	563	971588	79	572738	642	427262	30
31	9·544663	562	9·971540	79	9·573123	641	10·426877	29
32	545000	562	971493	79	573507	641	426493	28
33	545338	561	971446	79	573892	640	426108	27
34	545674	561	971398	79	574276	640	425724	26
35	546011	560	971351	79	574660	639	425340	25
36	546347	560	971303	79	575044	639	424956	24
37	546683	559	971256	79	575427	639	424573	23
38	547019	559	971208	79	575810	638	424190	22
39	547354	558	971161	79	576193	638	423807	21
40	547689	558	971113	79	576576	637	423424	20
41	9·548024	557	9·971066	80	9·576958	637	10·423041	19
42	548359	557	971018	80	577341	636	422659	18
43	548693	556	970970	80	577723	636	422277	17
44	549027	556	970922	80	578104	636	421896	16
45	549360	555	970874	80	578486	635	421514	15
46	549693	555	970827	80	578867	635	421133	14
47	550026	554	970779	80	579248	634	420752	13
48	550359	554	970731	80	579629	634	420371	12
49	550692	553	970683	80	580009	634	419991	11
50	551024	553	970635	80	580389	633	419611	10
51	9·551356	552	9·970586	80	9·580769	633	10·419231	9
52	551687	552	970538	80	581149	632	418851	8
53	552018	552	970490	80	581528	632	418472	7
54	552349	551	970442	80	581907	632	418093	6
55	552680	551	970394	80	582286	631	417714	5
56	553010	550	970345	81	582665	631	417335	4
57	553341	550	970297	81	583043	630	416957	3
58	553670	549	970249	81	583422	630	416578	2
59	554000	549	970200	81	583800	629	416200	1
60	554329	548	970152	81	584177	629	415823	0
	Cosine.		Sine.		Cotang.		Tang.	M.

69 Degrees.

21 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·554329	548	9·970152	81	9·584177	629	10·415823	60
1	554658	548	970103	81	584555	629	415445	59
2	554987	547	970055	81	584932	628	415068	58
3	555315	547	970006	81	585309	628	414691	57
4	555643	546	969957	81	585686	627	414314	56
5	555971	546	969909	81	586062	627	413938	55
6	556209	545	969860	81	586439	627	413561	54
7	556626	545	969811	81	586815	626	413185	53
8	556953	544	969762	81	587190	626	412810	52
9	557280	544	969714	81	587566	625	412434	51
10	557606	543	969665	81	587941	625	412059	50
11	9·557932	543	9·969616	82	9·588316	625	10·411684	49
12	558258	543	969567	82	588691	624	411309	48
13	558583	542	969518	82	589066	624	410934	47
14	558909	542	969469	82	589440	623	410560	46
15	559234	541	969420	82	589814	623	410186	45
16	559558	541	969370	82	590188	623	409812	44
17	559883	540	969321	82	590562	622	409438	43
18	560207	540	969272	82	590935	622	409065	42
19	560531	539	969223	82	591308	622	408692	41
20	560855	539	969173	82	591681	621	408319	40
21	9·561178	538	9·969124	82	9·592054	621	10·407946	39
22	561501	538	969075	82	592426	620	407574	38
23	561824	537	969025	82	592798	620	407202	37
24	562146	537	968976	82	593170	619	406829	36
25	562468	536	968926	83	593542	619	406458	35
26	562790	536	968877	83	593914	618	406086	34
27	563112	536	968827	83	594285	618	405715	33
28	563433	535	968777	83	594656	618	405344	32
29	563755	535	968728	83	595027	617	404973	31
30	564075	534	968678	83	595398	617	404602	30
31	9·564396	534	9·968628	83	9·595768	617	10·404232	29
32	564716	533	968578	83	596138	616	403862	28
33	565036	533	968528	83	596508	616	403492	27
34	565356	532	968479	83	596878	616	403122	26
35	565676	532	968429	83	597247	615	402753	25
36	565995	531	968379	83	597616	615	402384	24
37	566314	531	968329	83	597985	615	402015	23
38	566632	531	968278	83	598354	614	401646	22
39	566951	530	968228	84	598722	614	401278	21
40	567269	530	968178	84	599091	613	400909	20
41	9·567587	529	9·968128	84	9·599459	613	10·400541	19
42	567904	529	968078	84	599827	613	400173	18
43	568222	528	968027	84	600194	612	399806	17
44	568539	528	967977	84	600562	612	399438	16
45	568856	528	967927	84	600929	611	399071	15
46	569172	527	967876	84	601296	611	398704	14
47	569488	527	967826	84	601662	611	398338	13
48	569804	526	967775	84	602029	610	397971	12
49	570120	526	967725	84	602395	610	397605	11
50	570435	525	967674	84	602761	610	397239	10
51	9·570751	525	9·967624	84	9·603127	609	10·396873	9
52	571066	524	967573	84	603493	609	396507	8
53	571380	524	967522	85	603858	609	396142	7
54	571695	523	967471	85	604223	608	395777	6
55	572009	523	967421	85	604588	608	395412	5
56	572323	523	967370	85	604953	607	395047	4
57	572636	522	967319	85	605317	607	394683	3
58	572950	522	967268	85	605682	607	394318	2
59	573263	521	967217	85	606046	606	393954	1
60	573575	521	967166	85	606410	606	393590	0
	Cosine.		Sine.		Cotang.		Tang.	M.

68 Degrees.

22 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·573575	521	9·967166	85	9·606410	606	10·393590	60
1	573888	520	967115	85	606773	606	393227	59
2	574200	520	967064	85	607137	605	392863	58
3	574512	519	967013	85	607500	605	392500	57
4	574824	519	966961	85	607863	604	392137	56
5	575136	519	966910	85	608225	604	391775	55
6	575447	518	966859	85	608588	604	391412	54
7	575758	518	966808	85	608950	603	391050	53
8	576069	517	966756	86	609312	603	390688	52
9	576379	517	966705	86	609674	603	390326	51
10	576689	516	966653	86	610036	602	389964	50
11	9·576999	516	9·966602	86	9·610397	602	10·389603	49
12	577309	516	966550	86	610759	602	389241	48
13	577618	515	966499	86	611120	601	388880	47
14	577927	515	966447	86	611480	601	388520	46
15	578236	514	966395	86	611841	601	388159	45
16	578545	514	966344	86	612201	600	387799	44
17	578853	513	966292	86	612561	600	387439	43
18	579162	513	966240	86	612921	600	387079	42
19	579470	513	966188	86	613281	599	386719	41
20	579777	512	966136	86	613641	599	386359	40
21	9·580085	512	9·966085	87	9·614000	598	10·386000	39
22	580392	511	966033	87	614359	598	385641	38
23	580699	511	965981	87	614718	598	385282	37
24	581005	511	965928	87	615077	597	384923	36
25	581312	510	965876	87	615435	597	384565	35
26	581618	510	965824	87	615793	597	384207	34
27	581924	509	965772	87	616151	596	383849	33
28	582229	509	965720	87	616509	596	383491	32
29	582535	509	965668	87	616867	596	383133	31
30	582840	508	965615	87	617224	595	382776	30
31	9·583145	508	9·965563	87	9·617582	595	10·382418	29
32	583449	507	965511	87	617939	595	382061	28
33	583754	507	965458	87	618295	594	381705	27
34	584058	506	965406	87	618652	594	381348	26
35	584361	506	965353	88	619008	594	380992	25
36	584665	506	965301	88	619364	593	380636	24
37	584968	505	965248	88	619721	593	380279	23
38	585272	505	965195	88	620076	593	379924	22
39	585574	504	965143	88	620432	592	379568	21
40	585877	504	965090	88	620787	592	379213	20
41	9·586179	503	9·965037	88	9·621142	592	10·378858	19
42	586482	503	964984	88	621497	591	378503	18
43	586783	503	964931	88	621852	591	378148	17
44	587085	502	964879	88	622207	590	377793	16
45	587386	502	964826	88	622561	590	377439	15
46	587688	501	964773	88	622915	590	377085	14
47	587989	501	964719	88	623269	589	376731	13
48	588289	501	964666	89	623623	589	376377	12
49	588590	500	964613	89	623976	589	376024	11
50	588890	500	964560	89	624330	588	375670	10
51	9·589190	499	9·964507	89	9·624683	588	10·375317	9
52	589489	499	964454	89	625036	588	374964	8
53	589789	499	964400	89	625388	587	374612	7
54	590088	498	964347	89	625741	587	374259	6
55	590387	498	964294	89	626093	587	373907	5
56	590686	497	964240	89	626445	586	373555	4
57	590984	497	964187	89	626797	586	373203	3
58	591282	497	964133	89	627149	586	372851	2
59	591580	496	964080	89	627501	585	372499	1
60	591878	496	964026	89	627852	585	372148	0
	Cosine.		Sine.		Cotang.		Tang.	M.

67 Degrees.

C

23 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·591878	496	9·964026	89	9·627852	585	10·372148	60
1	592176	495	963972	89	628203	585	371797	59
2	592473	495	963919	89	628554	585	371446	58
3	592770	495	963865	90	628905	584	371095	57
4	593067	494	963811	90	629255	584	370745	56
5	593363	494	963757	90	629606	583	370394	55
6	593659	493	963704	90	629956	583	370044	54
7	593955	493	963650	90	630306	583	369694	53
8	594251	493	963596	90	630656	583	369344	52
9	594547	492	963542	90	631005	582	368995	51
10	594842	492	963488	90	631355	582	368645	50
11	9·595137	491	9·963434	90	9·631704	582	10·368296	49
12	595432	491	963379	90	632053	581	367947	48
13	595727	491	963325	90	632401	581	367599	47
14	596021	490	963271	90	632750	581	367250	46
15	596315	490	963217	90	633098	580	366902	45
16	596609	489	963163	90	633447	580	366553	44
17	596903	489	963108	91	633795	580	366205	43
18	597196	489	963054	91	634143	579	365857	42
19	597490	488	962999	91	634490	579	365510	41
20	597783	488	962945	91	634838	579	365162	40
21	9·598075	487	9·962890	91	9·635185	578	10·364815	39
22	598368	487	962836	91	635532	578	364468	38
23	598660	487	962781	91	635879	578	364121	37
24	598952	486	962727	91	636226	577	363774	36
25	599244	486	962672	91	636572	577	363428	35
26	599536	485	962617	91	636919	577	363081	34
27	599827	485	962562	91	637265	577	362735	33
28	600118	485	962508	91	637611	576	362389	32
29	600409	484	962453	91	637956	576	362044	31
30	600700	484	962398	92	638302	576	361698	30
31	9·600990	484	9·962343	92	9·638647	575	10·361353	29
32	601280	483	962288	92	638992	575	361008	28
33	601570	483	962233	92	639337	575	360663	27
34	601860	482	962178	92	639682	574	360318	26
35	602150	482	962123	92	640027	574	359973	25
36	602439	482	962067	92	640371	574	359629	24
37	602728	481	962012	92	640716	573	359284	23
38	603017	481	961957	92	641060	573	358940	22
39	603305	481	961902	92	641404	573	358596	21
40	603594	480	961846	92	641747	572	358253	20
41	9·603882	480	9·961791	92	9·642091	572	10·357909	19
42	604170	479	961735	92	642434	572	357566	18
43	604457	479	961680	92	642777	572	357223	17
44	604745	479	961624	93	643120	571	356880	16
45	605032	478	961569	93	643463	571	356537	15
46	605319	478	961513	93	643806	571	356194	14
47	605606	478	961458	93	644148	570	355852	13
48	605892	477	961402	93	644490	570	355510	12
49	606179	477	961346	93	644832	570	355168	11
50	606465	476	961290	93	645174	569	354826	10
51	9·606751	476	9·961235	93	9·645516	569	10·354484	9
52	607036	476	961179	93	645857	569	354143	8
53	607322	475	961123	93	646199	569	353801	7
54	607607	475	961067	93	646540	568	353460	6
55	607892	474	961011	93	646881	568	353119	5
56	608177	474	960955	93	647222	568	352778	4
57	608461	474	960899	93	647562	567	352438	3
58	608745	473	960843	94	647903	567	352097	2
59	609029	473	960786	94	648243	567	351757	1
60	609313	473	960730	94	648583	566	351417	0
	Cosine.		Sine.		Cotang.		Tang.	M.

66 Degrees.

24 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·609313	473	9·960730	94	9·648583	566	10·351417	60
1	609597	472	960674	94	648923	566	351077	59
2	609880	472	960618	94	649263	566	350737	58
3	610164	472	960561	94	649602	566	350398	57
4	610447	471	960505	94	649942	565	350058	56
5	610729	471	960448	94	650281	565	349719	55
6	611012	470	960392	94	650620	565	349380	54
7	611294	470	960335	94	650959	564	349041	53
8	611576	470	960279	94	651297	564	348703	52
9	611858	469	960222	94	651636	564	348364	51
10	612140	469	960165	94	651974	563	348026	50
11	9·612421	469	9·960109	95	9·652312	563	10·347688	49
12	612702	468	960052	95	652650	563	347350	48
13	612983	468	959995	95	652988	563	347012	47
14	613264	467	959938	95	653326	562	346674	46
15	613545	467	959882	95	653663	562	346337	45
16	613825	467	959825	95	654000	562	346000	44
17	614105	466	959768	95	654337	561	345663	43
18	614385	466	959711	95	654674	561	345326	42
19	614665	466	959654	95	655011	561	344989	41
20	614944	465	959596	95	655348	561	344652	40
21	9·615223	465	9·959539	95	9·655684	560	10·344316	39
22	615502	465	959482	95	656020	560	343980	38
23	615781	464	959425	95	656356	560	343644	37
24	616060	464	959368	95	656692	559	343308	36
25	616338	464	959310	96	657028	559	342972	35
26	616616	463	959253	96	657364	559	342636	34
27	616894	463	959195	96	657699	559	342301	33
28	617172	462	959138	96	658034	558	341966	32
29	617450	462	959081	96	658369	558	341631	31
30	617727	462	959023	96	658704	558	341296	30
31	9·618004	461	9·958965	96	9·659039	558	10·340961	29
32	618281	461	958908	96	659373	557	340627	28
33	618558	461	958850	96	659708	557	340292	27
34	618834	460	958792	96	660042	557	339958	26
35	619110	460	958734	96	660376	557	339624	25
36	619386	460	958677	96	660710	556	339290	24
37	619662	459	958619	96	661043	556	338957	23
38	619938	459	958561	96	661377	556	338623	22
39	620213	459	958503	97	661710	555	338290	21
40	620488	458	958445	97	662043	555	337957	20
41	9·620763	458	9·958387	97	9·662376	555	10·337624	19
42	621038	457	958329	97	662709	554	337291	18
43	621313	457	958271	97	663042	554	336958	17
44	621587	457	958213	97	663375	554	336625	16
45	621861	456	958154	97	663707	554	336293	15
46	622135	456	958096	97	664039	553	335961	14
47	622409	456	958038	97	664371	553	335629	13
48	622682	455	957979	97	664703	553	335297	12
49	622956	455	957921	97	665035	553	334965	11
50	623229	455	957863	97	665366	552	334634	10
51	9·623502	454	9·957804	97	9·665697	552	10·334303	9
52	623774	454	957746	98	666029	552	333971	8
53	624047	454	957687	98	666360	551	333640	7
54	624319	453	957628	98	666691	551	333309	6
55	624591	453	957570	98	667021	551	332979	5
56	624863	453	957511	98	667352	551	332648	4
57	625135	452	957452	98	667682	550	332318	3
58	625406	452	957393	98	668013	550	331987	2
59	625677	452	957335	98	668343	550	331657	1
60	625948	451	957276	98	668672	550	331328	0
	Cosine.		Sine.		Cotang.		Tang.	M.

65 Degrees.

25 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·625948	451	9·957276	98	9·668673	550	10·331327	60
1	626219	451	957217	98	669002	549	330998	59
2	626490	451	957158	98	669332	549	330668	58
3	626760	450	957099	98	669661	549	330339	57
4	627030	450	957040	98	669991	548	330009	56
5	627300	450	956981	98	670320	548	329680	55
6	627570	449	956921	99	670649	548	329351	54
7	627840	449	956862	99	670977	548	329023	53
8	628109	449	956803	99	671306	547	328694	52
9	628378	448	956744	99	671634	547	328366	51
10	628647	448	956684	99	671963	547	328037	50
11	9·628916	447	9·956625	99	9·672291	547	10·327709	49
12	629185	447	956566	99	672619	546	327381	48
13	629453	447	956506	99	672947	546	327053	47
14	629721	446	956447	99	673274	546	326726	46
15	629989	446	956387	99	673602	546	326398	45
16	630257	446	956327	99	673929	545	326071	44
17	630524	446	956268	99	674257	545	325743	43
18	630792	445	956208	100	674584	545	325416	42
19	631059	445	956148	100	674910	544	325090	41
20	631326	445	956089	100	675237	544	324763	40
21	9·631593	444	9·956029	100	9·675564	544	10·324436	39
22	631859	444	955969	100	675890	544	324110	38
23	632125	444	955909	100	676216	543	323784	37
24	632392	443	955849	100	676543	543	323457	36
25	632658	443	955789	100	676869	543	323131	35
26	632923	443	955729	100	677194	543	322806	34
27	633189	442	955669	100	677520	542	322480	33
28	633454	442	955609	100	677846	542	322154	32
29	633719	442	955548	100	678171	542	321829	31
30	633984	441	955488	100	678496	542	321504	30
31	9·634249	441	9·955428	101	9·678821	541	10·321179	29
32	634514	440	955368	101	679146	541	320854	28
33	634778	440	955307	101	679471	541	320529	27
34	635042	440	955247	101	679795	541	320205	26
35	635306	439	955186	101	680120	540	319880	25
36	635570	439	955126	101	680444	540	319556	24
37	635834	439	955065	101	680768	540	319232	23
38	636097	438	955005	101	681092	540	318908	22
39	636360	438	954944	101	681416	539	318584	21
40	636623	438	954883	101	681740	539	318260	20
41	9·636886	437	9·954823	101	9·682063	539	10·317937	19
42	637148	437	954762	101	682387	539	317613	18
43	637411	437	954701	101	682710	538	317290	17
44	637673	437	954640	101	683033	538	316967	16
45	637935	436	954579	101	683356	538	316644	15
46	638197	436	954518	102	683679	538	316321	14
47	638458	436	954457	102	684001	537	315999	13
48	638720	435	954396	102	684324	537	315676	12
49	638981	435	954335	102	684646	537	315354	11
50	639242	435	954274	102	684968	537	315032	10
51	9·639503	434	9·954213	102	9·685290	536	10·314710	9
52	639764	434	954152	102	685612	536	314388	8
53	640024	434	954090	102	685934	536	314066	7
54	640284	433	954029	102	686255	536	313745	6
55	640544	433	953968	102	686577	535	313423	5
56	640804	433	953906	102	686898	535	313102	4
57	641064	432	953845	102	687219	535	312781	3
58	641324	432	953783	102	687540	535	312460	2
59	641584	432	953722	103	687861	534	312139	1
60	641842	431	953660	103	688182	534	311818	0
	Cosine.		Sine.		Cotang.		Tang.	M.

64 Degrees.

26 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·641842	431	9·953660	103	9·688182	534	10·311818	60
1	642101	431	953599	103	688502	534	311498	59
2	642360	431	953537	103	688823	534	311177	58
3	642618	430	953475	103	689143	533	310857	57
4	642877	430	953413	103	689463	533	310537	56
5	643135	430	953352	103	689783	533	310217	55
6	643393	430	953290	103	690103	533	309897	54
7	643650	429	953228	103	690423	533	309577	53
8	643908	429	953166	103	690742	532	309258	52
9	644165	429	953104	103	691062	532	308938	51
10	644423	428	953042	103	691381	532	308619	50
11	9·644680	428	9·952980	104	9·691700	531	10·308300	49
12	644936	428	952918	104	692019	531	307981	48
13	645193	427	952855	104	692338	531	307662	47
14	645450	427	952793	104	692656	531	307344	46
15	645706	427	952731	104	692975	531	307025	45
16	645962	426	952669	104	693293	530	306707	44
17	646218	426	952606	104	693612	530	306388	43
18	646474	426	952544	104	693930	530	306070	42
19	646729	425	952481	104	694248	530	305752	41
20	646984	425	952419	104	694566	529	305434	40
21	9·647240	425	9·952356	104	9·694883	529	10·305117	39
22	647494	424	952294	104	695201	529	304799	38
23	647749	424	952231	104	695518	529	304482	37
24	648004	424	952168	105	695836	529	304164	36
25	648258	424	952106	105	696153	528	303847	35
26	648512	423	952043	105	696470	528	303530	34
27	648766	423	951980	105	696787	528	303213	33
28	649020	423	951917	105	697103	528	302897	32
29	649274	422	951854	105	697420	527	302580	31
30	649527	422	951791	105	697736	527	302264	30
31	9·649781	422	9·951728	105	9·698053	527	10·301947	29
32	650034	422	951665	105	698369	527	301631	28
33	650287	421	951602	105	698685	526	301315	27
34	650539	421	951539	105	699001	526	300999	26
35	650792	421	951476	105	699316	526	300684	25
36	651044	420	951412	105	699632	526	300368	24
37	651297	420	951349	106	699947	526	300053	23
38	651549	420	951286	106	700263	525	299737	22
39	651800	419	951222	106	700578	525	299422	21
40	652052	419	951159	106	700893	525	299107	20
41	9·652304	419	9·951096	106	9·701208	524	10·298792	19
42	652555	418	951032	106	701523	524	298477	18
43	652806	418	950968	106	701837	524	298163	17
44	653057	418	950905	106	702152	524	297848	16
45	653308	418	950841	106	702466	524	297534	15
46	653558	417	950778	106	702780	523	297220	14
47	653808	417	950714	106	703095	523	296905	13
48	654059	417	950650	106	703409	523	296591	12
49	654309	416	950586	106	703723	523	296277	11
50	654558	416	950522	107	704036	522	295964	10
51	9·654808	416	9·950458	107	9·704350	522	10·295650	9
52	655058	416	950394	107	704663	522	295337	8
53	655307	415	950330	107	704977	522	295023	7
54	655556	415	950266	107	705290	522	294710	6
55	655805	415	950202	107	705603	521	294397	5
56	656054	414	950138	107	705910	521	294084	4
57	656302	414	950074	107	706228	521	293772	3
58	656551	414	950010	107	706541	521	293459	2
59	656799	413	949945	107	706854	521	293146	1
60	657047	413	649881	107	707166	520	292834	0
	Cosine.		Sine.		Cotang.		Tang.	M.

63 Degrees.

27 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·657047	413	9·949881	107	9·707166	520	10·292834	60
1	657295	413	949816	107	707478	520	292522	59
2	657542	412	949752	107	707790	520	292210	58
3	657790	412	949688	108	708102	520	291898	57
4	658037	412	949623	108	708414	519	291586	56
5	658284	412	949558	108	708726	519	291274	55
6	658531	411	949494	108	709037	519	290963	54
7	658778	411	949429	108	709349	519	290651	53
8	659025	411	949364	108	709660	519	290340	52
9	659271	410	949300	108	709971	518	290029	51
10	659517	410	949235	108	710282	518	289718	50
11	9·659763	410	9·949170	108	9·710593	518	10·289407	49
12	660009	409	949105	108	710904	518	289096	48
13	660255	409	949040	108	711215	518	288785	47
14	660501	409	948975	108	711525	517	288475	46
15	660746	409	948910	108	711836	517	288164	45
16	660991	408	948845	108	712146	517	287854	44
17	661236	408	948780	109	712456	517	287544	43
18	661481	408	948715	109	712766	516	287234	42
19	661726	407	948650	109	713076	516	286924	41
20	661970	407	948584	109	713386	516	286614	40
21	9·662214	407	9·948519	109	9·713696	516	10·286304	39
22	662459	407	948454	109	714005	516	285995	38
23	662703	406	948388	109	714314	515	285686	37
24	662946	406	948323	109	714624	515	285376	36
25	663190	406	948257	109	714933	515	285067	35
26	663433	405	948192	109	715242	515	284758	34
27	663677	405	948126	109	715551	514	284449	33
28	663920	405	948060	109	715860	514	284140	32
29	664163	405	947995	110	716168	514	283832	31
30	664406	404	947929	110	716477	514	283523	30
31	9·664648	404	9·947863	110	9·716785	514	10·283215	29
32	664891	404	947797	110	717093	513	282907	28
33	665133	403	947731	110	717401	513	282599	27
34	665375	403	947665	110	717709	513	282291	26
35	665617	403	947600	110	718017	513	281983	25
36	665859	402	947533	110	718325	513	281675	24
37	666100	402	947467	110	718633	512	281367	23
38	666342	402	947401	110	718940	512	281060	22
39	666583	402	947335	110	719248	512	280752	21
40	666824	401	947269	110	719555	512	280445	20
41	9·667065	401	9·947203	110	9·719862	512	10·280138	19
42	667305	401	947136	111	720169	511	279831	18
43	667546	401	947070	111	720476	511	279524	17
44	667786	400	947004	111	720783	511	279217	16
45	668027	400	946937	111	721089	511	278911	15
46	668267	400	946871	111	721396	511	278604	14
47	668506	399	946804	111	721702	510	278298	13
48	668746	399	946738	111	722009	510	277991	12
49	668986	399	946671	111	722315	510	277685	11
50	669225	399	946604	111	722621	510	277379	10
51	9·669464	398	9·946538	111	9·722927	510	10·277073	9
52	669703	398	946471	111	723232	509	276768	8
53	669942	398	946404	111	723538	509	276462	7
54	670181	397	946337	111	723844	509	276156	6
55	670419	397	946270	112	724149	509	275851	5
56	670658	397	946203	112	724454	509	275546	4
57	670896	397	946136	112	724759	508	275241	3
58	671134	396	946069	112	725065	508	274935	2
59	671372	396	946002	112	725369	508	274631	1
60	671609	396	945935	112	725674	508	274326	0
	Cosine.		Sine.		Cotang.		Tang.	M.

62 Degrees.

28 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·671609	396	9·945935	112	9·725674	508	10·274326	60
1	671847	395	945868	112	725979	508	274021	59
2	672084	395	945800	112	726284	507	273716	58
3	672321	395	945733	112	726588	507	273412	57
4	672558	395	945666	112	726892	507	273108	56
5	672795	394	945598	112	727197	507	272803	55
6	673032	394	945531	112	727501	507	272499	54
7	673268	394	945464	113	727805	506	272195	53
8	673505	394	945396	113	728109	506	271891	52
9	673741	393	945328	113	728412	506	271588	51
10	673977	393	945261	113	728716	506	271284	50
11	9·674213	393	9·945193	113	9·729020	506	10·270980	49
12	674448	392	945125	113	729323	505	270677	48
13	674684	392	945058	113	729626	505	270374	47
14	674919	392	944990	113	729929	505	270071	46
15	675155	392	944922	113	730233	505	269767	45
16	675390	391	944854	113	730535	505	269465	44
17	675624	391	944786	113	730838	504	269162	43
18	675859	391	944718	113	731141	504	268859	42
19	676094	391	944650	113	731444	504	268556	41
20	676328	390	944582	114	731746	504	268254	40
21	9·676562	390	9·944514	114	9·732048	504	10·267952	39
22	676796	390	944446	114	732351	503	267649	38
23	677030	390	944377	114	732653	503	267347	37
24	677264	389	944309	114	732955	503	267045	36
25	677498	389	944241	114	733257	503	266743	35
26	677731	389	944172	114	733558	503	266442	34
27	677964	388	944104	114	733860	502	266140	33
28	678197	388	944036	114	734162	502	265838	32
29	678430	388	943967	114	734463	502	265537	31
30	678663	388	943899	114	734764	502	265236	30
31	9·678895	387	9·943830	114	9·735066	502	10·264934	29
32	679128	387	943761	114	735367	502	264633	28
33	679360	387	943693	115	735668	501	264332	27
34	679592	387	943624	115	735969	501	264031	26
35	679824	386	943555	115	736269	501	263731	25
36	680056	386	943486	115	736570	501	263430	24
37	680288	386	943417	115	736871	501	263129	23
38	680519	385	943348	115	737171	500	262829	22
39	680750	385	943279	115	737471	500	262529	21
40	680982	385	943210	115	737771	500	262229	20
41	9·681213	385	9·943141	115	9·738071	500	10·261929	19
42	681443	384	943072	115	738371	500	261629	18
43	681674	384	943003	115	738671	499	261329	17
44	681905	384	942934	115	738971	499	261029	16
45	682135	384	942864	115	739271	499	260729	15
46	682365	383	942795	116	739570	499	260430	14
47	682595	383	942726	116	739870	499	260130	13
48	682825	383	942656	116	740169	499	259831	12
49	683055	383	942587	116	740468	498	259532	11
50	683284	382	942517	116	740767	498	259233	10
51	9·683514	382	9·942448	116	9·741066	498	10·258934	9
52	683743	382	942378	116	741365	498	258635	8
53	683972	382	942308	116	741664	498	258336	7
54	684201	381	942239	116	741962	497	258038	6
55	684430	381	942169	116	742261	497	257739	5
56	684658	381	942099	116	742559	497	257441	4
57	684887	380	942029	116	742858	497	257142	3
58	685115	380	941959	116	743156	497	256844	2
59	685343	380	941889	117	743454	497	256546	1
60	685571	380	941819	117	743752	496	256248	0
	Cosine.		Sine.		Cotang.		Tang.	M.

61 Degrees.

29 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·685571	880	9·941819	117	9·743752	496	10·256248	60
1	685799	379	941749	117	744050	496	255950	59
2	686027	379	941679	117	744348	496	255652	58
3	686254	379	941609	117	744645	496	255355	57
4	686482	379	941539	117	744943	496	255057	56
5	686709	378	941469	117	745240	496	254760	55
6	686936	378	941398	117	745538	495	254462	54
7	687163	378	941328	117	745835	495	254165	53
8	687389	378	941258	117	746132	495	253868	52
9	687616	377	941187	117	746429	495	253571	51
10	687843	377	941117	117	746726	495	253274	50
11	9·688069	377	9·941046	118	9·747023	494	10·252977	49
12	688295	377	940975	118	747319	494	252681	48
13	688521	376	940905	118	747616	494	252384	47
14	688747	376	940834	118	747913	494	252087	46
15	688972	376	940763	118	748209	494	251791	45
16	689198	376	940693	118	748505	493	251495	44
17	689423	375	940622	118	748801	493	251199	43
18	689648	375	940551	118	749097	493	250903	42
19	689873	375	940480	118	749393	493	250607	41
20	690098	375	940409	118	749689	493	250311	40
21	9·690323	374	9·940338	118	9·749985	493	10·250015	39
22	690548	374	940267	118	750281	492	249719	38
23	690772	374	940196	118	750576	492	249424	37
24	690996	374	940125	119	750872	492	249128	36
25	691220	373	940054	119	751167	492	248833	35
26	691444	373	939982	119	751462	492	248538	34
27	691668	373	939911	119	751757	492	248243	33
28	691892	373	939840	119	752052	491	247948	32
29	692115	372	939768	119	752347	491	247653	31
30	692339	372	939697	119	752642	491	247358	30
31	9·692562	372	9·939625	119	9·752937	491	10·247063	29
32	692785	371	939554	119	753231	491	246769	28
33	693008	371	939482	119	753526	491	246474	27
34	693231	371	939410	119	753820	490	246180	26
35	693453	371	939339	119	754115	490	245885	25
36	693676	370	939267	120	754409	490	245591	24
37	693898	370	939195	120	754703	490	245297	23
38	694120	370	939123	120	754997	490	245003	22
39	694342	370	939052	120	755291	490	244709	21
40	694564	369	938980	120	755585	489	244415	20
41	9·694786	369	9·938908	120	9·755878	489	10·244122	19
42	695007	369	938836	120	756172	489	243828	18
43	695229	369	938763	120	756465	489	243535	17
44	695450	368	938691	120	756759	489	243241	16
45	695671	368	938619	120	757052	489	242948	15
46	695892	368	938547	120	757345	488	242655	14
47	696113	368	938475	120	757638	488	242362	13
48	696334	367	938402	121	757931	488	242069	12
49	696554	367	938330	121	758224	488	241776	11
50	696775	367	938258	121	758517	488	241483	10
51	9·696995	367	9·938185	121	9·758810	488	10·241190	9
52	697215	366	938113	121	759102	487	240898	8
53	697435	366	938040	121	759395	487	240605	7
54	697654	366	937967	121	759687	487	240313	6
55	697874	366	937895	121	759979	487	240021	5
56	698094	365	937822	121	760272	487	239728	4
57	698313	365	937749	121	760564	487	239436	3
58	698532	365	937676	121	760856	486	239144	2
59	698751	365	937604	121	761148	486	238852	1
60	698970	364	937531	121	761439	486	238561	0
	Cosine.		Sine.		Cotang.		Tang.	M.

60 Degrees.

30 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·698970	364	9·937531	121	9·761439	486	10·238561	60
1	699189	364	937458	122	761731	486	238269	59
2	699407	364	937385	122	762023	486	237977	58
3	699626	364	937312	122	762314	486	237686	57
4	699844	363	937238	122	762606	485	237394	56
5	700062	363	937165	122	762897	485	237103	55
6	700280	363	937092	122	763188	485	236812	54
7	700498	363	937019	122	763479	485	236521	53
8	700716	363	936946	122	763770	485	236230	52
9	700933	362	936872	122	764061	485	235939	51
10	701151	362	936799	122	764352	484	235648	50
11	9·701368	362	9·936725	122	9·764643	484	10·235357	49
12	701585	362	936652	123	764933	484	235067	48
13	701802	361	936578	123	765224	484	234776	47
14	702019	361	936505	123	765514	484	234486	46
15	702236	361	936431	123	765805	484	234195	45
16	702452	361	936357	123	766095	484	233905	44
17	702669	360	936284	123	766385	483	233615	43
18	702885	360	936210	123	766675	483	233325	42
19	703101	360	936136	123	766965	483	233035	41
20	703317	360	936062	123	767255	483	232745	40
21	9·703533	359	9·935988	123	9·767545	483	10·232455	39
22	703749	359	935914	123	767834	483	232166	38
23	703964	359	935840	123	768124	482	231876	37
24	704179	359	935766	124	768413	482	231587	36
25	704395	359	935692	124	768703	482	231297	35
26	704610	358	935618	124	768992	482	231008	34
27	704825	358	935543	124	769281	482	230719	33
28	705040	358	935469	124	769570	482	230430	32
29	705254	358	935395	124	769860	481	230140	31
30	705469	357	935320	124	770148	481	229852	30
31	9·705683	357	9·935246	124	9·770437	481	10·229563	29
32	705898	357	935171	124	770726	481	229274	28
33	706112	357	935097	124	771015	481	228985	27
34	706326	356	935022	124	771303	481	228697	26
35	706539	356	934948	124	771592	481	228408	25
36	706753	356	934873	124	771880	480	228120	24
37	706967	356	934798	125	772168	480	227832	23
38	707180	355	934723	125	772457	480	227543	22
39	707393	355	934649	125	772745	480	227255	21
40	707606	355	934574	125	773033	480	226967	20
41	9·707819	355	9·934499	125	9·773321	480	10·226679	19
42	708032	354	934424	125	773608	479	226392	18
43	708245	354	934349	125	773896	479	226104	17
44	708458	354	934274	125	774184	479	225816	16
45	708670	354	934199	125	774471	479	225529	15
46	708882	353	934123	125	774759	479	225241	14
47	709094	353	934048	125	775046	479	224954	13
48	709306	353	933973	125	775333	479	224667	12
49	709518	353	933898	126	775621	478	224379	11
50	709730	353	933822	126	775908	478	224092	10
51	9·709941	352	9·933747	126	9·776195	478	10·223805	9
52	710153	352	933671	126	776482	478	223518	8
53	710364	352	933596	126	776769	478	223231	7
54	710575	352	933520	126	777055	478	222945	6
55	710786	351	933445	126	777342	478	222658	5
56	710997	351	933369	126	777628	477	222372	4
57	711208	351	933293	126	777915	477	222085	3
58	711419	351	933217	126	778201	477	221799	2
59	711629	350	933141	126	778487	477	221512	1
60	711839	350	933066	126	778774	477	221226	0
	Cosine.		Sine.		Cotang.		Tang.	M.

59 Degrees.

31 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·711839	350	9·933066	126	9·778774	477	10·221226	60
1	712050	350	932990	127	779060	477	220940	59
2	712260	350	932914	127	779346	476	220654	58
3	712469	349	932838	127	779632	476	220368	57
4	712679	349	932762	127	779918	476	220082	56
5	712889	349	932685	127	780203	476	219797	55
6	713098	349	932609	127	780489	476	219511	54
7	713308	349	932533	127	780775	476	219225	53
8	713517	348	932457	127	781060	476	218940	52
9	713726	348	932380	127	781346	475	218654	51
10	713935	348	932304	127	781631	475	218369	50
11	9·714144	348	9·932228	127	9·781916	475	10·218084	49
12	714352	347	932151	127	782201	475	217799	48
13	714561	347	932075	128	782486	475	217514	47
14	714769	347	931998	128	782771	475	217229	46
15	714978	347	931921	128	783056	475	216944	45
16	715186	347	931845	128	783341	475	216659	44
17	715394	346	931768	128	783626	474	216374	43
18	715602	346	931691	128	783910	474	216090	42
19	715809	346	931614	128	784195	474	215805	41
20	716017	346	931537	128	784479	474	215521	40
21	9·716224	345	9·931460	128	9·784764	474	10·215236	39
22	716432	345	931383	128	785048	474	214952	38
23	716639	345	931306	128	785332	473	214668	37
24	716846	345	931229	129	785616	473	214384	36
25	717053	345	931152	129	785900	473	214100	35
26	717259	344	931075	129	786184	473	213816	34
27	717466	344	930998	129	786468	473	213532	33
28	717673	344	930921	129	786752	473	213248	32
29	717879	344	930843	129	787036	473	212964	31
30	718085	343	930766	129	787319	472	212681	30
31	9·718291	343	9·930688	129	9·787603	472	10·212397	29
32	718497	343	930611	129	787886	472	212114	28
33	718703	343	930533	129	788170	472	211830	27
34	718909	343	930456	129	788453	472	211547	26
35	719114	342	930378	129	788736	472	211264	25
36	719320	342	930300	130	789019	472	210981	24
37	719525	342	930223	130	789302	471	210698	23
38	719730	342	930145	130	789585	471	210415	22
39	719935	341	930067	130	789868	471	210132	21
40	720140	341	929989	130	790151	471	209849	20
41	9·720345	341	9·929911	130	9·790433	471	10·209567	19
42	720549	341	929833	130	790716	471	209284	18
43	720754	340	929755	130	790999	471	209001	17
44	720958	340	929677	130	791281	471	208719	16
45	721162	340	929599	130	791563	470	208437	15
46	721366	340	929521	130	791846	470	208154	14
47	721570	340	929442	130	792128	470	207872	13
48	721774	339	929364	131	792410	470	207590	12
49	721978	339	929286	131	792692	470	207308	11
50	722181	339	929207	131	792974	470	207026	10
51	9·722385	339	9·929129	131	9·793256	470	10·206744	9
52	722588	339	929050	131	793538	469	206462	8
53	722791	338	928972	131	793819	469	206181	7
54	722994	338	928893	131	794101	469	205899	6
55	723197	338	928815	131	794383	469	205617	5
56	723400	338	928736	131	794664	469	205336	4
57	723603	337	928657	131	794945	469	205055	3
58	723805	337	928578	131	795227	469	204773	2
59	724007	337	928499	131	795508	468	204492	1
60	724210	337	928420	131	795789	468	204211	0
	Cosine.		Sine.		Cotang.		Tang.	M.

58 Degrees.

32 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·724210	337	9·928420	132	9·795789	468	10·204211	60
1	724412	337	928342	132	796070	468	203930	59
2	724614	336	928263	132	796351	468	203649	58
3	724816	336	928183	132	796632	468	203368	57
4	725017	336	928104	132	796913	468	203087	56
5	725219	336	928025	132	797194	468	202806	55
6	725420	335	927946	132	797475	468	202525	54
7	725622	335	927867	132	797755	468	202245	53
8	725823	335	927787	132	798036	467	201964	52
9	726024	335	927708	132	798316	467	201684	51
10	726225	335	927629	132	798596	467	201404	50
11	9·726426	334	9·927549	132	9·798877	467	10·201123	49
12	726626	334	927470	133	799157	467	200843	48
13	726827	334	927390	133	799437	467	200563	47
14	727027	334	927310	133	799717	467	200283	46
15	727228	334	927231	133	799997	466	200003	45
16	727428	333	927151	133	800277	466	199723	44
17	727628	333	927071	133	800557	466	199443	43
18	727828	333	926991	133	800836	466	199164	42
19	728027	333	926911	133	801116	466	198884	41
20	728227	333	926831	133	801396	466	198604	40
21	9·728427	332	9·926751	133	9·801675	466	10·198325	39
22	728626	332	926671	133	801955	466	198045	38
23	728825	332	926591	133	802234	465	197766	37
24	729024	332	926511	134	802513	465	197487	36
25	729223	331	926431	134	802792	465	197208	35
26	729422	331	926351	134	803072	465	196928	34
27	729621	331	926270	134	803351	465	196649	33
28	729820	331	926190	134	803630	465	196370	32
29	730018	330	926110	134	803908	465	196092	31
30	730216	330	926029	134	804187	465	195813	30
31	9·730415	330	9·925949	134	9·804466	464	10·195534	29
32	730613	330	925868	134	804745	464	195255	28
33	730811	330	925788	134	805023	464	194977	27
34	731009	329	925707	134	805302	464	194698	26
35	731206	329	925626	134	805580	464	194420	25
36	731404	329	925545	135	805859	464	194141	24
37	731602	329	925465	135	806137	464	193863	23
38	731799	329	925384	135	806415	463	193585	22
39	731996	328	925303	135	806693	463	193307	21
40	732193	328	925222	135	806971	463	193029	20
41	9·732390	328	9·925141	135	9·807249	463	10·192751	19
42	732587	328	925060	135	807527	463	192473	18
43	732784	328	924979	135	807805	463	192195	17
44	732980	327	924897	135	808083	463	191917	16
45	733177	327	924816	135	808361	463	191639	15
46	733373	327	924735	136	808638	462	191362	14
47	733569	327	924654	136	808916	462	191084	13
48	733765	327	924572	136	809193	462	190807	12
49	733961	326	924491	136	809471	462	190529	11
50	734157	326	924409	136	809748	462	190252	10
51	9·734353	326	9·924328	136	9·810025	462	10·189975	9
52	734549	326	924246	136	810302	462	189698	8
53	734744	325	924164	136	810580	462	189420	7
54	734939	325	924083	136	810857	462	189143	6
55	735135	325	924001	136	811134	461	188866	5
56	735330	325	923919	136	811410	461	188590	4
57	735525	325	923837	136	811687	461	188313	3
58	735719	324	923755	137	811964	461	188036	2
59	735914	324	923673	137	812241	461	187759	1
60	736109	324	923591	137	812517	461	187483	0
	Cosine.		Sine.		Cotang.		Tang.	M.

57 Degrees.

33 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·736109	324	9·923591	137	9·812517	461	10·187482	60
1	736303	324	923509	137	812794	461	187206	59
2	736498	324	923427	137	813070	461	186930	58
3	736692	323	923345	137	813347	460	186653	57
4	736886	323	923263	137	813623	460	186377	56
5	737080	323	923181	137	813899	460	186101	55
6	737274	323	923098	137	814175	460	185825	54
7	737467	323	923016	137	814452	460	185548	53
8	737661	322	922933	137	814728	460	185272	52
9	737855	322	922851	137	815004	460	184996	51
10	738048	322	922768	138	815279	460	184721	50
11	9·738241	322	9·922686	138	9·815555	459	10·184445	49
12	738434	322	922603	138	815831	459	184169	48
13	738627	321	922520	138	816107	459	183893	47
14	738820	321	922438	138	816382	459	183618	46
15	739013	321	922355	138	816658	459	183342	45
16	739206	321	922272	138	816933	459	183067	44
17	739398	321	922189	138	817209	459	182791	43
18	739590	320	922106	138	817484	459	182516	42
19	739783	320	922023	138	817759	459	182241	41
20	739975	320	921940	138	818035	458	181965	40
21	9·740167	320	9·921857	139	9·818310	458	10·181690	39
22	740359	320	921774	139	818585	458	181415	38
23	740550	319	921691	139	818860	458	181140	37
24	740742	319	921607	139	819135	458	180865	36
25	740934	319	921524	139	819410	458	180590	35
26	741125	319	921441	139	819684	458	180316	34
27	741316	319	921357	139	819959	458	180041	33
28	741508	318	921274	139	820234	458	179766	32
29	741699	318	921190	139	820508	457	179492	31
30	741889	318	921107	139	820783	457	179217	30
31	9·742080	318	9·921023	139	9·821057	457	10·178943	29
32	742271	318	920939	140	821332	457	178668	28
33	742462	317	920856	140	821606	457	178394	27
34	742652	317	920772	140	821880	457	178120	26
35	742842	317	920688	140	822154	457	177846	25
36	743033	317	920604	140	822429	457	177571	24
37	743223	317	920520	140	822703	457	177297	23
38	743413	316	920436	140	822977	456	177023	22
39	743602	316	920352	140	823250	456	176750	21
40	743792	316	920268	140	823524	456	176476	20
41	9·743982	316	9·920184	140	9·823798	456	10·176202	19
42	744171	316	920099	140	824072	456	175928	18
43	744361	315	920015	140	824345	456	175655	17
44	744550	315	919931	141	824619	456	175381	16
45	744739	315	919846	141	824893	456	175107	15
46	744928	315	919762	141	825166	456	174834	14
47	745117	315	919677	141	825439	455	174561	13
48	745306	314	919593	141	825713	455	174287	12
49	745494	314	919508	141	825986	455	174014	11
50	745683	314	919424	141	826259	455	173741	10
51	9·745871	314	9·919339	141	9·826532	455	10·173468	9
52	746059	314	919254	141	826805	455	173195	8
53	746248	313	919169	141	827078	455	172922	7
54	746436	313	919085	141	827351	455	172649	6
55	746624	313	919000	141	827624	455	172376	5
56	746812	313	918915	142	827897	454	172103	4
57	746999	313	918830	142	828170	454	171830	3
58	747187	312	918745	142	828442	454	171558	2
59	747374	312	918659	142	828715	454	171285	1
60	747562	312	918574	142	828987	454	171013	0
	Cosine.		Sine.		Cotang.		Tang.	M.

56 Degrees.

34 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·747562	312	9·918574	142	9·828987	454	10·171018	60
1	747749	312	918489	142	829260	454	170740	59
2	747936	312	918404	142	829532	454	170468	58
3	748123	311	918318	142	829805	454	170195	57
4	748310	311	918233	142	830077	454	169923	56
5	748497	311	918147	142	830349	453	169651	55
6	748683	311	918062	142	830621	453	169379	54
7	748870	311	917976	143	830893	453	169107	53
8	749056	310	917891	143	831165	453	168835	52
9	749243	310	917805	143	831437	453	168563	51
10	749429	310	917719	143	831709	453	168291	50
11	9·749615	310	9·917634	143	9·831981	453	10·168019	49
12	749801	310	917548	143	832253	453	167747	48
13	749987	309	917462	143	832525	453	167475	47
14	750172	309	917376	143	832796	453	167204	46
15	750358	309	917290	143	833068	452	166932	45
16	750543	309	917204	143	833339	452	166661	44
17	750729	309	917118	144	833611	452	166389	43
18	750914	308	917032	144	833882	452	166118	42
19	751099	308	916946	144	834154	452	165846	41
20	751284	308	916859	144	834425	452	165575	40
21	9·751469	308	9·916773	144	9·834696	452	10·165304	39
22	751654	308	916687	144	834967	452	165033	38
23	751839	308	916600	144	835238	452	164762	37
24	752023	307	916514	144	835509	452	164491	36
25	752208	307	916427	144	835780	451	164220	35
26	752392	307	916341	144	836051	451	163949	34
27	752576	307	916254	144	836322	451	163678	33
28	752760	307	916167	145	836593	451	163407	32
29	752944	306	916081	145	836864	451	163136	31
30	753128	306	915994	145	837134	451	162866	30
31	9·753312	306	9·915907	145	9·837405	451	10·162595	29
32	753495	306	915820	145	837675	451	162325	28
33	753679	306	915733	145	837946	451	162054	27
34	753862	305	915646	145	838216	451	161784	26
35	754046	305	915559	145	838487	450	161513	25
36	754229	305	915472	145	838757	450	161243	24
37	754412	305	915385	145	839027	450	160973	23
38	754595	305	915297	145	839297	450	160703	22
39	754778	304	915210	145	839568	450	160432	21
40	754960	304	915123	146	839838	450	160162	20
41	9·755143	304	9·915035	146	9·840108	450	10·159892	19
42	755326	304	914948	146	840378	450	159622	18
43	755508	304	914860	146	840647	450	159353	17
44	755690	304	914773	146	840917	449	159083	16
45	755872	303	914685	146	841187	449	158813	15
46	756054	303	914598	146	841457	449	158543	14
47	756236	303	914510	146	841726	449	158274	13
48	756418	303	914422	146	841996	449	158004	12
49	756600	303	914334	146	842266	449	157734	11
50	756782	302	914246	147	842535	449	157465	10
51	9·756963	302	9·914158	147	9·842805	449	10·157195	9
52	757144	302	914070	147	843074	449	156926	8
53	757326	302	913982	147	843343	449	156657	7
54	757507	302	913894	147	843612	449	156388	6
55	757688	301	913806	147	843882	448	156118	5
56	757869	301	913718	147	844151	448	155849	4
57	758050	301	913630	147	844420	448	155580	3
58	758230	301	913541	147	844689	448	155311	2
59	758411	301	913453	147	844958	448	155042	1
60	758591	301	913365	147	845227	448	154773	0
	Cosine.		Sine.		Cotang.		Tang.	M.

55 Degrees.

35 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·758591	301	9·913365	147	9·845227	448	10·154773	60
1	758772	300	913276	147	845496	448	154504	59
2	758952	300	913187	148	845764	448	154236	58
3	759132	300	913099	148	846033	448	153967	57
4	759312	300	913010	148	846302	448	153698	56
5	759492	300	912922	148	846570	447	153430	55
6	759672	299	912833	148	846839	447	153161	54
7	759852	299	912744	148	847107	447	152893	53
8	760031	299	912655	148	847376	447	152624	52
9	760211	299	912566	148	847644	447	152356	51
10	760390	299	912477	148	847913	447	152087	50
11	9·760569	298	9·912388	148	9·848181	447	10·151819	49
12	760748	298	912299	149	848449	447	151551	48
13	760927	298	912210	149	848717	447	151283	47
14	761106	298	912121	149	848986	447	151014	46
15	761285	298	912031	149	849254	447	150746	45
16	761464	298	911942	149	849522	447	150478	44
17	761642	297	911853	149	849790	446	150210	43
18	761821	297	911763	149	850058	446	149942	42
19	761999	297	911674	149	850325	446	149675	41
20	762177	297	911584	149	850593	446	149407	40
21	9·762356	297	9·911495	149	9·850861	446	10·149139	39
22	762534	296	911405	149	851129	446	148871	38
23	762712	296	911315	150	851396	446	148604	37
24	762889	296	911226	150	851664	446	148336	36
25	763067	296	911136	150	851931	446	148069	35
26	763245	296	911046	150	852199	446	147801	34
27	763422	296	910956	150	852466	446	147534	33
28	763600	295	910866	150	852733	445	147267	32
29	763777	295	910776	150	853001	445	146999	31
30	763954	295	910686	150	853268	445	146732	30
31	9·764131	295	9·910596	150	9·853535	445	10·146465	29
32	764308	295	910506	150	853802	445	146198	28
33	764485	294	910415	150	854069	445	145931	27
34	764662	294	910325	151	854336	445	145664	26
35	764838	294	910235	151	854603	445	145397	25
36	765015	294	910144	151	854870	445	145130	24
37	765191	294	910054	151	855137	445	144863	23
38	765367	294	909963	151	855404	445	144596	22
39	765544	293	909873	151	855671	444	144329	21
40	765720	293	909782	151	855938	444	144062	20
41	9·765896	293	9·909691	151	9·856204	444	10·143796	19
42	766072	293	909601	151	856471	444	143529	18
43	766247	293	909510	151	856737	444	143263	17
44	766423	293	909419	151	857004	444	142996	16
45	766598	292	909328	152	857270	444	142730	15
46	766774	292	909237	152	857537	444	142463	14
47	766949	292	909146	152	857803	444	142197	13
48	767124	292	909055	152	858069	444	141931	12
49	767300	292	908964	152	858336	444	141664	11
50	767475	291	908873	152	858602	443	141398	10
51	9·767649	291	9·908781	152	9·858868	443	10·141132	9
52	767824	291	908690	152	859134	443	140866	8
53	767999	291	908599	152	859400	443	140600	7
54	768173	291	908507	152	859666	443	140334	6
55	768348	290	908416	153	859932	443	140068	5
56	768522	290	908324	153	860198	443	139802	4
57	768697	290	908233	153	860464	443	139536	3
58	768871	290	908141	153	860730	443	139270	2
59	769045	290	908049	153	860995	443	139005	1
60	769219	290	907958	153	861261	443	138739	0
	Cosine.		Sine.		Cotang.		Tang.	M.

54 Degrees.

36 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·769219	290	9·907958	153	9·861261	443	10·138739	60
1	769393	289	907866	153	861527	443	138473	59
2	769566	289	907774	153	861792	442	138208	58
3	769740	289	907682	153	862058	442	137942	57
4	769913	289	907590	153	862323	442	137677	56
5	770087	289	907498	153	862589	442	137411	55
6	770260	288	907406	153	862854	442	137146	54
7	770433	288	907314	154	863119	442	136881	53
8	770606	288	907222	154	863385	442	136615	52
9	770779	288	907129	154	863650	442	136350	51
10	770952	288	907037	154	863915	442	136085	50
11	9·771125	288	9·906945	154	9·864180	442	10·135820	49
12	771298	287	906852	154	864445	442	135555	48
13	771470	287	906760	154	864710	442	135290	47
14	771643	287	906667	154	864975	441	135025	46
15	771815	287	906575	154	865240	441	134760	45
16	771987	287	906482	154	865505	441	134495	44
17	772159	287	906389	155	865770	441	134230	43
18	772331	286	906296	155	866035	441	133965	42
19	772503	286	906204	155	866300	441	133700	41
20	772675	286	906111	155	866564	441	133436	40
21	9·772847	286	9·906018	155	9·866829	441	10·133171	39
22	773018	286	905925	155	867094	441	132906	38
23	773190	286	905832	155	867358	441	132642	37
24	773361	285	905739	155	867623	441	132377	36
25	773533	285	905645	155	867887	441	132113	35
26	773704	285	905552	155	868152	440	131848	34
27	773875	285	905459	155	868416	440	131584	33
28	774046	285	905366	156	868680	440	131320	32
29	774217	285	905272	156	868945	440	131055	31
30	774388	284	905179	156	869209	440	130791	30
31	9·774558	284	9·905085	156	9·869473	440	10·130527	29
32	774729	284	904992	156	869737	440	130263	28
33	774899	284	904898	156	870001	440	129999	27
34	775070	284	904804	156	870265	440	129735	26
35	775240	284	904711	156	870529	440	129471	25
36	775410	283	904617	156	870793	440	129207	24
37	775580	283	904523	156	871057	440	128943	23
38	775750	283	904429	157	871321	440	128679	22
39	775920	283	904335	157	871585	440	128415	21
40	776090	283	904241	157	871849	439	128151	20
41	9·776259	283	9·904147	157	9·872112	439	10·127888	19
42	776429	282	904053	157	872376	439	127624	18
43	776598	282	903959	157	872640	439	127360	17
44	776768	282	903864	157	872903	439	127097	16
45	776937	282	903770	157	873167	439	126833	15
46	777106	282	903676	157	873430	439	126570	14
47	777275	281	903581	157	873694	439	126306	13
48	777444	281	903487	157	873957	439	126043	12
49	777613	281	903392	158	874220	439	125780	11
50	777781	281	903298	158	874484	439	125516	10
51	9·777950	281	9·903203	158	9·874747	439	10·125253	9
52	778119	281	903108	158	875010	439	124990	8
53	778287	280	903014	158	875273	438	124727	7
54	778455	280	902919	158	875536	438	124464	6
55	778624	280	902824	158	875800	438	124200	5
56	778792	280	902729	158	876063	438	123937	4
57	778960	280	902634	158	876326	438	123674	3
58	779128	280	902539	159	876589	438	123411	2
59	779295	279	902444	159	876851	438	123149	1
60	779463	279	902349	159	877114	438	122886	0
	Cosine.		Sine.		Cotang.		Tang.	M.

53 Degrees.

37 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·779463	279	9·902349	159	9·877114	438	10·122886	60
1	779631	279	902253	159	877377	438	122623	59
2	779798	279	902158	159	877640	438	122360	58
3	779966	279	902063	159	877903	438	122097	57
4	780133	279	901967	159	878165	438	121835	56
5	780300	278	901872	159	878428	438	121572	55
6	780467	278	901776	159	878691	438	121309	54
7	780634	278	901681	159	878953	437	121047	53
8	780801	278	901585	159	879216	437	120784	52
9	780968	278	901490	159	879478	437	120522	51
10	781134	278	901394	160	879741	437	120259	50
11	9·781301	277	9·901298	160	9·880003	437	10·119997	49
12	781468	277	901202	160	880265	437	119735	48
13	781634	277	901106	160	880528	437	119472	47
14	781800	277	901010	160	880790	437	119210	46
15	781966	277	900914	160	881052	437	118948	45
16	782132	277	900818	160	881314	437	118686	44
17	782298	276	900722	160	881576	437	118424	43
18	782464	276	900626	160	881839	437	118161	42
19	782630	276	900529	160	882101	437	117899	41
20	782796	276	900433	161	882363	436	117637	40
21	9·782961	276	9·900337	161	9·882625	436	10·117375	39
22	783127	276	900240	161	882887	436	117113	38
23	783292	275	900144	161	883148	436	116852	37
24	783458	275	900047	161	883410	436	116590	36
25	783623	275	899951	161	883672	436	116328	35
26	783788	275	899854	161	883934	436	116066	34
27	783953	275	899757	161	884196	436	115804	33
28	784118	275	899660	161	884457	436	115543	32
29	784282	274	899564	161	884719	436	115281	31
30	784447	274	899467	162	884980	436	115020	30
31	9·784612	274	9·899370	162	9·885242	436	10·114758	29
32	784776	274	899273	162	885503	436	114497	28
33	784941	274	899176	162	885765	436	114235	27
34	785105	274	899078	162	886026	436	113974	26
35	785269	273	898981	162	886288	436	113712	25
36	785433	273	898884	162	886549	435	113451	24
37	785597	273	898787	162	886810	435	113190	23
38	785761	273	898689	162	887072	435	112928	22
39	785925	273	898592	162	887333	435	112667	21
40	786089	273	898494	163	887594	435	112406	20
41	9·786252	272	9·898397	163	9·887855	435	10·112145	19
42	786416	272	898299	163	888116	435	111884	18
43	786579	272	898202	163	888377	435	111623	17
44	786742	272	898104	163	888639	435	111361	16
45	786906	272	898006	163	888900	435	111100	15
46	787069	272	897908	163	889160	435	110840	14
47	787232	271	897810	163	889421	435	110579	13
48	787395	271	897712	163	889682	435	110318	12
49	787557	271	897614	163	889943	435	110057	11
50	787720	271	897516	163	890204	434	109796	10
51	9·787883	271	9·897418	164	9·890465	434	10·109535	9
52	788045	271	897320	164	890725	434	109275	8
53	788208	271	897222	164	890986	434	109014	7
54	788370	270	897123	164	891247	434	108753	6
55	788532	270	897025	164	891507	434	108493	5
56	788694	270	896926	164	891768	434	108232	4
57	788856	270	896828	164	892028	434	107972	3
58	789018	270	896729	164	892289	434	107711	2
59	789180	270	896631	164	892549	434	107451	1
60	789342	269	896532	164	892810	434	107190	0
	Cosine.		Sine.		Cotang.		Tang.	M.

52 Degrees.

38 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·789342	269	9·896532	164	9.892810	434	10·107190	60
1	789504	269	896433	165	893070	434	106930	59
2	789665	269	896335	165	893331	434	106669	58
3	789827	269	896236	165	893591	434	106409	57
4	789988	269	896137	165	893851	434	106149	56
5	790149	269	896038	165	894111	434	105889	55
6	790310	268	895939	165	894371	434	105629	54
7	790471	268	895840	165	894632	433	105368	53
8	790632	268	895741	165	894892	433	105108	52
9	790793	268	895641	165	895152	433	104848	51
10	790954	268	895542	165	895412	433	104588	50
11	9·791115	268	9·895443	166	9·895672	433	10·104328	49
12	791275	267	895343	166	895932	433	104068	48
13	791436	267	895244	166	896192	433	103808	47
14	791596	267	895145	166	896452	433	103548	46
15	791757	267	895045	166	896712	433	103288	45
16	791917	267	894945	166	896971	433	103029	44
17	792077	267	894846	166	897231	433	102769	43
18	792237	266	894746	166	897491	433	102509	42
19	792397	266	894646	166	897751	433	102249	41
20	792557	266	894546	166	898010	433	101990	40
21	9·792716	266	9·894446	167	9·898270	433	10·101730	39
22	792876	266	894346	167	898530	433	101470	38
23	793035	266	894246	167	898789	433	101211	37
24	793195	265	894146	167	899049	432	100951	36
25	793354	265	894046	167	899308	432	100692	35
26	793514	265	893946	167	899568	432	100432	34
27	793673	265	893846	167	899827	432	100172	33
28	793832	265	893745	167	900086	432	099914	32
29	793991	265	893645	167	900346	432	099654	31
30	794150	264	893544	167	900605	432	099395	30
31	9·794308	264	9·893444	168	9·900864	432	10·099136	29
32	794467	264	893343	168	901124	432	098876	28
33	794626	264	893243	168	901383	432	098617	27
34	794784	264	893142	168	901642	432	098358	26
35	794942	264	893041	168	901901	432	098099	25
36	795101	264	892940	168	902160	432	097840	24
37	795259	264	892839	168	902419	432	097581	23
38	795417	263	892739	168	902679	432	097321	22
39	795575	263	892638	168	902938	432	097062	21
40	795733	263	892536	168	903197	431	096803	20
41	9·795891	263	9·892435	169	9·903455	431	10·096545	19
42	796049	263	892334	169	903714	431	096286	18
43	796206	263	892233	169	903973	431	096027	17
44	796364	262	892132	169	904232	431	095768	16
45	796521	262	892030	169	904491	431	095509	15
46	796679	262	891929	169	904750	431	095250	14
47	796836	262	891827	169	905008	431	094992	13
48	796993	262	891726	169	905267	431	094733	12
49	797150	261	891624	169	905526	431	094474	11
50	797307	261	891523	170	905784	431	094216	10
51	9·797464	261	9·891421	170	9·906043	431	10·093957	9
52	797621	261	891319	170	906302	431	093698	8
53	797777	261	891217	170	906560	431	093440	7
54	797934	261	891115	170	906819	431	093181	6
55	798091	261	891013	170	907077	431	092923	5
56	798247	261	890911	170	907336	431	092664	4
57	798403	260	890809	170	907594	431	092406	3
58	798560	260	890707	170	907852	431	092148	2
59	798716	260	890605	170	908111	430	091889	1
60	798872	260	890503	170	908369	430	091631	0
	Cosine.		Sine.		Cotang.		Tang.	M.

51 Degrees.

39 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·798872	260	9·890503	170	9·908369	430	10·091631	60
1	799028	260	890400	171	908628	430	091372	59
2	799184	260	890298	171	908886	430	091114	58
3	799339	259	890195	171	909144	430	090856	57
4	799495	259	890093	171	909402	430	090598	56
5	799651	259	889990	171	909660	430	090340	55
6	799806	259	889888	171	909918	430	090082	54
7	799962	259	889785	171	910177	430	089823	53
8	800117	259	889682	171	910435	430	089565	52
9	800272	258	889579	171	910693	430	089307	51
10	800427	258	889477	171	910951	430	089049	50
11	9·800582	258	9·889374	172	9·911209	430	10·088791	49
12	800737	258	889271	172	911467	430	088533	48
13	800892	258	889168	172	911724	430	088276	47
14	801047	258	889064	172	911982	430	088018	46
15	801201	258	888961	172	912240	430	087760	45
16	801356	257	888858	172	912498	430	087502	44
17	801511	257	888755	172	912756	430	087244	43
18	801665	257	888651	172	913014	429	086986	42
19	801819	257	888548	172	913271	429	086729	41
20	801973	257	888444	173	913529	429	086471	40
21	9·802128	257	9·888341	173	9·913787	429	10·086213	39
22	802282	256	888237	173	914044	429	085956	38
23	802436	256	888134	173	914302	429	085698	37
24	802589	256	888030	173	914560	429	085440	36
25	802743	256	887926	173	914817	429	085183	35
26	802897	256	887822	173	915075	429	084925	34
27	803050	256	887718	173	915332	429	084668	33
28	803204	256	887614	173	915590	429	084410	32
29	803357	255	887510	173	915847	429	084153	31
30	803511	255	887406	174	916104	429	083896	30
31	9·803664	255	9·887302	174	9·916362	429	10·083638	29
32	803817	255	887198	174	916619	429	083381	28
33	803970	255	887093	174	916877	429	083123	27
34	804123	255	886989	174	917134	429	082866	26
35	804276	254	886885	174	917391	429	082609	25
36	804428	254	886780	174	917648	429	082352	24
37	804581	254	886676	174	917905	429	082095	23
38	804734	254	886571	174	918163	428	081837	22
39	804886	254	886466	174	918420	428	081580	21
40	805039	254	886362	175	918677	428	081323	20
41	9·805191	254	9·886257	175	9·918934	428	10·081066	19
42	805343	253	886152	175	919191	428	080809	18
43	805495	253	886047	175	919448	428	080552	17
44	805647	253	885942	175	919705	428	080295	16
45	805799	253	885837	175	919962	428	080038	15
46	805951	253	885732	175	920219	428	079781	14
47	806103	253	885627	175	920476	428	079524	13
48	806254	253	885522	175	920733	428	079267	12
49	806406	252	885416	175	920990	428	079010	11
50	806557	252	885311	176	921247	428	078753	10
51	9·806709	252	9·885205	176	9·921503	428	10·078497	9
52	806860	252	885100	176	921760	428	078240	8
53	807011	252	884994	176	922017	428	077983	7
54	807163	252	884889	176	922274	428	077726	6
55	807314	252	884783	176	922530	428	077470	5
56	807465	251	884677	176	922787	428	077213	4
57	807615	251	884572	176	923044	428	076956	3
58	807766	251	884466	176	923300	428	076700	2
59	807917	251	884360	176	923557	427	076443	1
60	808067	251	884254	177	923813	427	076187	0
	Cosine.		Sine.		Cotang.		Tang.	M.

50 Degrees.

40 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·808067	251	9·884254	177	9·923813	427	10·076187	60
1	808218	251	884148	177	924070	427	075930	59
2	808368	251	884042	177	924327	427	075673	58
3	808519	250	883936	177	924583	427	075417	57
4	808669	250	883829	177	924840	427	075160	56
5	808819	250	883723	177	925096	427	074904	55
6	808969	250	883617	177	925352	427	074648	54
7	809119	250	883510	177	925609	427	074391	53
8	809269	250	883404	177	925865	427	074135	52
9	809419	249	883297	178	926122	427	073878	51
10	809569	249	883191	178	926378	427	073622	50
11	9·809718	249	9·883084	178	9·926634	427	10·073366	49
12	809868	249	882977	178	926890	427	073110	48
13	810017	249	882871	178	927147	427	072853	47
14	810167	249	882764	178	927403	427	072597	46
15	810316	248	882657	178	927659	427	072341	45
16	810465	248	882550	178	927915	427	072085	44
17	810614	248	882443	178	928171	427	071829	43
18	810763	248	882336	179	928427	427	071573	42
19	810912	248	882229	179	928683	427	071317	41
20	811061	248	882121	179	928940	427	071060	40
21	9·811210	248	9·882014	179	9·929196	427	10·070804	39
22	811358	247	881907	179	929452	427	070548	38
23	811507	247	881799	179	929708	427	070292	37
24	811655	247	881692	179	929964	426	070036	36
25	811804	247	881584	179	930220	426	069780	35
26	811952	247	881477	179	930475	426	069525	34
27	812100	247	881369	179	930731	426	069269	33
28	812248	247	881261	180	930987	426	069013	32
29	812396	246	881153	180	931243	426	068757	31
30	812544	246	881046	180	931499	426	068501	30
31	9·812692	246	9·880938	180	9·931755	426	10·068245	29
32	812840	246	880830	180	932010	426	067990	28
33	812988	246	880722	180	932266	426	067734	27
34	813135	246	880613	180	932522	426	067478	26
35	813283	246	880505	180	932778	426	067222	25
36	813430	245	880397	180	933033	426	066967	24
37	813578	245	880289	181	933289	426	066711	23
38	813725	245	880180	181	933545	426	066455	22
39	813872	245	880072	181	933800	426	066200	21
40	814019	245	879963	181	934056	426	065944	20
41	9·814166	245	9·879855	181	9·934311	426	10·065689	19
42	814313	245	879746	181	934567	426	065433	18
43	814460	244	879637	181	934823	426	065177	17
44	814607	244	879529	181	935078	426	064922	16
45	814753	244	879420	181	935333	426	064667	15
46	814900	244	879311	181	935589	426	064411	14
47	815046	244	879202	182	935844	426	064156	13
48	815193	244	879093	182	936100	426	063900	12
49	815339	244	878984	182	936355	426	063645	11
50	815485	243	878875	182	936610	426	063390	10
51	9·815631	243	9·878766	182	9·936866	425	10·063134	9
52	815778	243	878656	182	937121	425	062879	8
53	815924	243	878547	182	937376	425	062624	7
54	816069	243	878438	182	937632	425	062368	6
55	816215	243	878328	182	937887	425	062113	5
56	816361	243	878219	183	938142	425	061858	4
57	816507	242	878109	183	938398	425	061602	3
58	816652	242	877999	183	938653	425	061347	2
59	816798	242	877890	183	938908	425	061092	1
60	816943	242	877780	183	939163	425	060837	0
	Cosine.		Sine.		Cotang.		Tang.	M.

49 Degrees.

41 Degrees.

M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·816943	242	9·877780	183	9·939163	425	10·060837	60
1	817088	242	877670	183	939418	425	060582	59
2	817233	242	877560	183	939673	425	060327	58
3	817379	242	877450	183	939928	425	060072	57
4	817524	241	877340	183	940183	425	059817	56
5	817668	241	877230	184	940438	425	059562	55
6	817813	241	877120	184	940694	425	059306	54
7	817958	241	877010	184	940949	425	059051	53
8	818103	241	876899	184	941204	425	058796	52
9	818247	241	876789	184	941458	425	058542	51
10	818392	241	876678	184	941714	425	058286	50
11	9·818536	240	9·876568	184	9·941968	425	10·058032	49
12	818681	240	876457	184	942223	425	057777	48
13	818825	240	876347	184	942478	425	057522	47
14	818969	240	876236	185	942733	425	057267	46
15	819113	240	876125	185	942988	425	057012	45
16	819257	240	876014	185	943243	425	056757	44
17	819401	240	875904	185	943498	425	056502	43
18	819545	239	875793	185	943752	425	056248	42
19	819689	239	875682	185	944007	425	055993	41
20	819832	239	875571	185	944262	425	055738	40
21	9·819976	239	9·875459	185	9·944517	425	10·055483	39
22	820120	239	875348	185	944771	424	055229	38
23	820263	239	875237	185	945026	424	054974	37
24	820406	239	875126	186	945281	424	054719	36
25	820550	238	875014	186	945535	424	054465	35
26	820693	238	874903	186	945790	424	054210	34
27	820836	238	874791	186	946045	424	053955	33
28	820979	238	874680	186	946299	424	053701	32
29	821122	238	874568	186	946554	424	053446	31
30	821265	238	874456	186	946808	424	053192	30
31	9·821407	238	9·874344	186	9·947063	424	10·052937	29
32	821550	238	874232	187	947318	424	052682	28
33	821693	237	874121	187	947572	424	052428	27
34	821835	237	874009	187	947826	424	052174	26
35	821977	237	873896	187	948081	424	051919	25
36	822120	237	873784	187	948336	424	051664	24
37	822262	237	873672	187	948590	424	051410	23
38	822404	237	873560	187	948844	424	051156	22
39	822546	237	873448	187	949099	424	050901	21
40	822688	236	873335	187	949353	424	050647	20
41	9·822830	236	9·873223	187	9·949607	424	10·050393	19
42	822972	236	873110	188	949862	424	050138	18
43	823114	236	872998	188	950116	424	049884	17
44	823255	236	872885	188	950370	424	049630	16
45	823397	236	872772	188	950625	424	049375	15
46	823539	236	872659	188	950879	424	049121	14
47	823680	235	872547	188	951133	424	048867	13
48	823821	235	872434	188	951388	424	048612	12
49	823963	235	872321	188	951642	424	048358	11
50	824104	235	872208	188	951896	424	048104	10
51	9·824245	235	9·872095	189	9·952150	424	10·047850	9
52	824386	235	871981	189	952405	424	047595	8
53	824527	235	871868	189	952659	424	047341	7
54	824668	234	871755	189	952913	424	047087	6
55	824808	234	871641	189	953167	423	046833	5
56	824949	234	871528	189	953421	423	046579	4
57	825090	234	871414	189	953675	423	046325	3
58	825230	234	871301	189	953929	423	046071	2
59	825371	234	871187	189	954183	423	045817	1
60	825511	234	871073	190	954437	423	045563	0
	Cosine.		Sine.		Cotang.		Tang.	M.

48 Degrees.

42 Degrees.

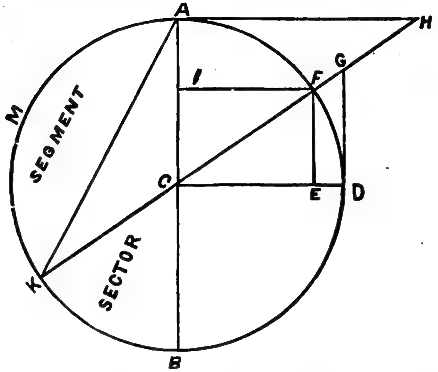
M.	Sine.	D.	Cosine.	D.	Tang.	D.	Cotang.	
0	9·825511	234	9·871073	190	9·954437	423	10·045563	60
1	825651	233	870960	190	954691	423	045309	59
2	825791	233	870846	190	954945	423	045055	58
3	825931	233	870732	190	955200	423	044800	57
4	826071	233	870618	190	955454	423	044546	56
5	826211	233	870504	190	955707	423	044293	55
6	826351	233	870390	190	955961	423	044039	54
7	826491	233	870276	190	956215	423	043785	53
8	826631	233	870161	190	956469	423	043531	52
9	826770	232	870047	191	956723	423	043277	51
10	826910	232	869933	191	956977	423	043023	50
11	9·827049	232	9·869818	191	9·957231	423	10·042769	49
12	827189	232	869704	191	957485	423	042515	48
13	827328	232	869589	191	957739	423	042261	47
14	827467	232	869474	191	957993	423	042007	46
15	827606	232	869360	191	958246	423	041754	45
16	827745	232	869245	191	958500	423	041500	44
17	827884	231	869130	191	958754	423	041246	43
18	828023	231	869015	192	959008	423	040992	42
19	828162	231	868900	192	959262	423	040738	41
20	828301	231	868785	192	959516	423	040484	40
21	9·828439	231	9·868670	192	9·959769	423	10·040231	39
22	828578	231	868555	192	960023	423	039977	38
23	828716	231	868440	192	960277	423	039723	37
24	828855	230	868324	192	960531	423	039469	36
25	828993	230	868209	192	960784	423	039216	35
26	829131	230	868093	192	961038	423	038962	34
27	829269	230	867978	193	961291	423	038709	33
28	829407	230	867862	193	961545	423	038455	32
29	829545	230	867747	193	961799	423	038201	31
30	829683	230	867631	193	962052	423	037948	30
31	9·829821	229	9·867515	193	9·962306	423	10·037694	29
32	829959	229	867399	193	962560	423	037440	28
33	830097	229	867283	193	962813	423	037187	27
34	830234	229	867167	193	963067	423	036933	26
35	830372	229	867051	193	963320	423	036680	25
36	830509	229	866935	194	963574	423	036426	24
37	830646	229	866819	194	963827	423	036173	23
38	830784	229	866703	194	964081	423	035919	22
39	830921	228	866586	194	964335	423	035665	21
40	831058	228	866470	194	964588	422	035412	20
41	9·831195	228	9·866353	194	9·964842	422	10·035158	19
42	831332	228	866237	194	965095	422	034905	18
43	831469	228	866120	194	965349	422	034651	17
44	831606	228	866004	195	965602	422	034398	16
45	831742	228	865887	195	965855	422	034145	15
46	831879	228	865770	195	966109	422	033891	14
47	832015	227	865653	195	966362	422	033638	13
48	832152	227	865536	195	966616	422	033384	12
49	832288	227	865419	195	966869	422	033131	11
50	832425	227	865302	195	967123	422	032877	10
51	9·832561	227	9·865185	195	9·967376	422	10·032624	9
52	832697	227	865068	195	967629	422	032371	8
53	832833	227	864950	195	967883	422	032117	7
54	832969	226	864833	196	968136	422	031864	6
55	833105	226	864716	196	968389	422	031611	5
56	833241	226	864598	196	968643	422	031357	4
57	833377	226	864481	196	968896	422	031104	3
58	833512	226	864363	196	969149	422	030851	2
59	833648	226	864245	196	969403	422	030597	1
60	833783	226	864127	196	969656	422	030344	0
	Cosine.		Sine.		Cotang.		Tang.	M.

47 Degrees.

NATURAL SINES, COSINES, TANGENTS, AND COTANGENTS.

The uses to which a table of natural sines, cosines, tangents, and cotangents can be put are numerous, but in this instance their usefulness to mining officials only will be shown.

The following cut shows what each is, in relation to an angle :



F E or I C	= Sine of angle F C E.	A M K	= Arc.
F I or C E	= Cosine.	A B	= Diameter.
D G	= Tangent.		
A H	= Cotangent.		
E D	= Versed Sine.		
A I	= Coversine.		
C D	= Radius.		
A K	= Chord.		

Segment is the space included between the chord A K and the arc A M K.

Sector is the space included between the radii C B and C K and the arc B K.

TRIGONOMETRICAL EQUIVALENTS.

$\sqrt{(1 - \text{Sine}^2)}$ = Cos.	$\sqrt{(1 - \text{Cos.}^2)}$ = Sine.
Sine ÷ Tan. = Cos.	1 + Cot. = Tan.
Sine × Cot. = Cos.	1 ÷ Sine = Cosec.
Sine ÷ Cos. = Tan.	1 ÷ Cos. = Sec.
Cos. ÷ Sine = Cot.	1 ÷ Cosec. = Sine.
Cos. ÷ Cot. = Sine.	1 ÷ Sec. = Cos.
Tan. ÷ Sine = Sec.	1 ÷ Tan. = Cot.
Tan. ÷ Sec. = Sine.	1 − Cos. = Versine.
Tan. × Cot. = Rad.	1 − Sine = Coversine.

Horizontal distance	= natural cosine	×	pitch distance.
Horizontal distance	= vertical distance	÷	natural tangent.
Vertical distance	= natural sine	×	pitch distance.
Vertical distance	= natural tangent	×	horizontal distance.
Pitch distance	= horizontal distance	÷	natural cosine.
Pitch distance	= vertical distance	÷	natural sine.
Vertical distance	÷ horizontal distance	=	tangent of angle.
Vertical distance	÷ pitch distance	=	sine of angle.

To find the strain on a rope hoisting on an incline.—1 is to sine of angle of inclination as the net weight of the load is to the strain on the rope.

EXAMPLE.—If a wagon weighing 4 tons is being hoisted up an incline of 30°, what is the strain on the rope, independent of friction and weight of the rope?

$$1 : \cdot 50000 \text{ or sine of } 30^\circ :: 4 \text{ tons} : (\ ), \text{ or } \frac{\cdot 50000 \times 4}{1} = 2 \text{ tons.}$$

To find the cubical contents of coal-seams.—4840, or number of sq. yds. in an acre, multiplied by the thickness of the seam, and the result divided by the cosine of the angle of inclination, gives the cubical contents per acre.

This table is also used in the solution of problems in connection with right-angled triangles. Let us suppose, for instance, there is a seam of coal dipping at an angle of 35° westward, and it is desired to sink a shaft 300 feet west of the outcropping. When the surface is level it is plain that the seam, the line from the outcropping to the shaft, and the shaft, when sunk, form a right-angled triangle. The line on the surface can be taken as the cosine, while the shaft forms the sine I C on diagram, page 64*a*, and the seam forms the radius. Hence, we make the following proportion:

Cosine 35° Sine 35°
As ·81915 : ·57358 :: 300 : 210 feet, the depth of the shaft.

Or the surface line may be taken as the radius, the shaft as the tangent, and the seam as the secant. See diagram on page 64*a*. Then, as

Radius Tangent 35°
1 : ·70021 :: 300 : 210 feet, the depth of the shaft.

Again, let us suppose in a shaft there is a seam 50 feet from the bottom, dipping at an angle of 30° east, it is desired to drive a tunnel from the bottom of the shaft across the measures till it meets the seam. The distance from the bottom of the shaft to the seam can be taken as the sine, the tunnel as the cosine, and the seam as the radius, thus:

Sine 30° Cosine 30°
As ·5 : ·86603 :: 50 : 86·6 feet, the length of the tunnel.

The table is further used for finding the northing and southing, easting and westing of a survey. Thus, if we desire to know the northing and easting of N. 18° E., 56 links, we find in the table opposite 18°, ·95106 cosine and ·30902 sine, which multiplied by 56 gives 53·26 northing and 17·3 of easting, and the distance between the extreme points may be found as follows:

$$\sqrt{53 \cdot 26^2 + 17 \cdot 3^2} = 56 \text{ nearly.}$$

Natural Sines.

′	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	′
0	000000	017452	034899	052336	069756	087156	104528	121869	139173	156434	60
5	1454	8907	6353	3788	071207	8605	5975	3313	140613	7871	55
10	2909	020361	7806	5241	2658	090053	7421	4756	2053	9307	50
15	4363	1815	9260	6693	4108	1502	8867	6199	3493	160743	45
20	5818	3269	040713	8145	5559	2950	110313	7642	4932	2178	40
25	7272	4723	2166	9597	7009	4398	1758	9084	6371	3613	35
30	8727	6177	3619	061049	8459	5846	3203	130526	7809	5048	30
35	010181	7631	5072	2500	9909	7293	4648	1968	9248	6482	25
40	1635	9085	6525	3952	081359	8741	6093	3410	150686	7916	20
45	3090	030539	7978	5403	2808	100188	7537	4851	2123	9350	15
50	4544	1992	9431	6854	4258	1635	8982	6292	3561	170783	10
55	5998	3446	050883	8306	5707	3082	120426	7783	4998	2216	5
60	7452	4899	2336	9756	7156	4528	1869	9173	6434	3648	0
Cos.	89°	88°	87°	86°	85°	84°	83°	82°	81°	80°	

Sine	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	
0	173648	190809	207912	224951	241922	258819	275637	292372	309017	325568	60
5	5080	2237	9334	6368	3333	260224	7035	3762	310400	6943	55
10	6512	3664	210756	7784	4743	1628	8432	5152	1782	8317	50
15	7944	5090	2178	9200	6153	3031	9829	6542	3164	9691	45
20	9375	6517	3599	230616	7563	4434	281225	7930	4545	331063	40
25	180805	7942	5019	2031	8972	5837	2620	9318	5925	2435	35
30	2236	9368	6440	3445	250380	7238	4015	300706	7305	3807	30
35	3665	200793	7859	4859	1788	8640	5410	2093	8684	5178	25
40	5095	2218	9279	6273	3195	270040	6803	3479	320062	6547	20
45	6524	3642	220697	7686	4602	1440	8196	4864	1439	7917	15
50	7953	5065	2116	9098	6008	2840	9589	6249	2816	9285	10
55	9381	6489	3534	240510	7414	4239	290981	7633	4193	340653	5
60	190809	7912	4951	1922	8819	5637	2372	9017	5568	2020	0
Cos.	79°	78°	77°	76°	75°	74°	73°	72°	71°	70°	

Sine	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	
0	342020	358368	374607	390731	406737	422618	438371	453990	469472	484810	60
5	3387	9725	5955	2070	8065	3936	9678	5286	470755	6081	55
10	4752	361082	7302	3407	9392	5253	440984	6580	2038	7352	50
15	6117	2438	8649	4744	410719	6569	2289	7874	3320	8621	45
20	7481	3793	9994	6080	2045	7884	3593	9166	4600	9890	40
25	8845	5148	381339	7415	3368	9198	4896	460458	5880	491157	35
30	350207	6501	2683	8749	4693	430511	6198	1749	7159	2424	30
35	1569	7854	4027	400082	6016	1823	7499	3038	8436	3689	25
40	2931	9206	5369	1415	7338	3135	8799	4327	9713	4953	20
45	4291	370557	6711	2747	8660	4445	450098	5615	480989	6217	15
50	5651	1908	8052	4078	9980	5755	1397	6901	2263	7479	10
55	7010	3258	9392	5408	421300	7063	2694	8187	3537	8740	5
60	8368	4607	390731	6737	2618	8371	3990	9472	4810	500000	0
Cos.	69°	68°	67°	66°	65°	64°	63°	62°	61°	60°	

Sine	30°	31°	32°	33°	34°	35°	36°	37°	38°	39°	
0	500000	515038	529919	544639	559193	573576	587785	601815	615661	629320	60
5	1259	6284	531152	5858	560398	4767	8961	2976	6807	630450	55
10	2517	7529	2384	7076	1602	5957	590136	4136	7951	1578	50
15	3774	8773	3615	8293	2805	7145	1310	5294	9094	2705	45
20	5030	520016	4844	9509	4007	8332	2482	6451	620235	3831	40
25	6285	1258	6072	550724	5207	9518	3653	7607	1376	4955	35
30	7538	2499	7300	1937	6406	580703	4823	8761	2515	6078	30
35	8791	3738	8526	3149	7604	1886	5991	9915	3652	7200	25
40	510043	4977	9751	4360	8801	3069	7159	611067	4789	8320	20
45	1293	6214	540974	5570	9997	4250	8325	2217	5923	9439	15
50	2543	7450	2197	6779	571191	5429	9489	3367	7057	640557	10
55	3791	8685	3419	7987	2384	6608	600653	4515	8189	1673	5
60	5038	9919	4639	9193	8576	7785	1815	5661	9320	2788	0
′	59°	58°	57°	56°	55°	54°	53°	52°	51°	50°	′

Natural Cosines.

Natural Sines.

′	40°	41°	42°	43°	44°	45°	46°	47°	48°	49°	′
0	642788	656059	669131	681998	694658	707107	719340	731354	743145	754710	60
5	3901	7156	670211	3061	5704	8134	720349	2345	4117	5663	55
10	5013	8252	1289	4123	6748	9161	1357	3334	5088	6615	50
15	6124	9346	2367	5183	7790	710185	2364	4323	6057	7565	45
20	7233	660439	3443	6242	8832	1209	3369	5309	7025	8514	40
25	8341	1530	4517	7299	9871	2230	4372	6294	7991	9461	35
30	9448	2620	5590	8355	700909	3250	5374	7277	8956	760406	30
35	650553	3709	6662	9409	1946	4269	6375	8259	9919	1350	25
40	1657	4796	7732	690462	2981	5286	7374	9239	750880	2292	20
45	2760	5882	8801	1513	4015	6302	8371	740218	1840	3232	15
50	3861	6966	9868	2563	5047	7316	9367	1195	2798	4171	10
55	4961	8049	680934	3611	6078	8329	730361	2171	3755	5109	5
60	6059	9131	1998	4658	7107	9340	1354	3145	4710	6044	0
Cos.	49°	48°	47°	46°	45°	44°	43°	42°	41°	40°	

Sine	50°	51°	52°	53°	54°	55°	56°	57°	58°	59°	
0	766044	777146	788011	798636	809017	819152	829038	838671	848048	857167	60
5	6979	8060	8905	9510	9871	9985	9850	9462	8818	7915	55
10	7911	8973	9798	800383	810723	820817	830661	840251	9586	8662	50
15	8842	9884	790690	1254	1574	1647	1470	1039	850352	9406	45
20	9771	780794	1579	2123	2423	2475	2277	1825	1117	860149	40
25	770699	1702	2467	2991	3270	3302	3082	2609	1879	0890	35
30	1625	2608	3353	3857	4116	4126	3886	3391	2640	1629	30
35	2549	3513	4238	4721	4959	4949	4688	4172	3399	2366	25
40	3472	4416	5121	5584	5801	5770	5488	4951	4156	3102	20
45	4303	5317	6002	6445	6642	6590	6286	5728	4912	3836	15
50	5312	6217	6882	7304	7480	7407	7088	6503	5665	4567	10
55	6230	7114	7759	8161	8317	8223	7878	7277	6417	5297	5
60	7146	8011	8636	9017	9152	9038	8671	8048	7167	6025	0
Co.	39°	38°	37°	36°	35°	34°	33°	32°	31°	30°	

Sine	60°	61°	62°	63°	64°	65°	66°	67°	68°	69°	
0	866025	874620	882948	891007	898794	906308	913545	920505	927184	933580	60
5	6752	5324	3629	1666	9431	6922	4136	1072	7728	4101	55
10	7476	6026	4309	2323	900065	7533	4725	1638	8270	4619	50
15	8199	6727	4988	2979	0698	8143	5311	2201	8810	5135	45
20	8920	7425	5664	3633	1329	8751	5896	2762	9348	5650	40
25	9639	8122	6338	4284	1958	9357	6479	3322	9884	6162	35
30	870356	8817	7011	4934	2585	9961	7060	3880	930418	6672	30
35	1071	9510	7681	5582	3210	910563	7639	4435	0950	7181	25
40	1784	880201	8350	6229	3834	1164	8216	4989	1480	7687	20
45	2496	0891	9017	6873	4455	1762	8791	5541	2008	8191	15
50	3206	1578	9682	7515	5075	2358	9364	6090	2534	8694	10
55	3914	2264	890345	8156	5692	2953	9936	6638	3058	9194	5
60	4620	2948	1007	8794	6308	3545	920505	7184	3580	9693	0
Cos.	29°	28°	27°	26°	25°	24°	23°	22°	21°	20°	

Sine	70°	71°	72°	73°	74°	75°	76°	77°	78°	79°	
0	939693	945519	951057	956305	961262	965926	970296	974370	978148	981627	60
5	940189	5991	1505	6729	1662	6301	0647	4696	8449	1904	55
10	0684	6462	1951	7151	2059	6675	0995	5020	8748	2178	50
15	1176	6930	2396	7571	2455	7046	1342	5342	9045	2450	45
20	1666	7397	2838	7990	2849	7415	1687	5662	9341	2721	40
25	2155	7861	3279	8406	3241	7782	2029	5980	9634	2989	35
30	2641	8324	3717	8820	3630	8148	2370	6296	9925	3255	30
35	3126	8784	4153	9232	4018	8511	2708	6610	980214	3519	25
40	3609	9248	4588	9642	4404	8872	3045	6921	0500	3781	20
45	4089	9699	5020	960050	4787	9231	3379	7231	0785	4041	15
50	4568	950154	5450	0456	5169	9588	3712	7539	1068	4298	10
55	5044	0606	5879	0860	5548	9943	4042	7844	1349	4554	5
60	5519	1057	6305	1262	5926	970296	4370	8148	1627	4808	0
′	19°	18°	17°	16°	15°	14°	13°	12°	11°	10°	′

Natural Cosines.

Natural Sines.

′	80°	81°	82°	83°	84°	85°	86°	87°	88°	89°	′
0	984808	987688	990268	992546	994522	996195	997564	998630	999391	999848	60
5	5059	7915	0469	2722	4673	6320	7664	8705	9441	9872	55
10	5309	8139	0669	2896	4822	6444	7763	8778	9488	9894	50
15	5556	8362	0866	8068	4969	6566	7859	8848	9534	9914	45
20	5801	8582	1061	3238	5113	6685	7953	8917	9577	9932	40
25	6045	8800	1254	3406	5256	6802	8045	8984	9618	9948	35
38	6286	9016	1445	3572	5396	6917	8135	9048	9657	9962	30
35	6525	9230	1634	3735	5535	7030	8223	9111	9694	9974	25
40	6762	9442	1820	3897	5671	7141	8308	9171	9729	9983	20
45	6996	9651	2005	4056	5805	7250	8392	9229	9762	9990	15
50	7229	9859	2187	4214	5937	7357	8473	9285	9793	9996	10
55	7460	990065	2368	4369	6067	7462	8552	9339	9824	9999	5
60	7688	0268	2546	4522	6195	75641	8630	9391	9848	1·000000	0
Cos.	9°	8°	7°	6°	5°	4°	3°	2°	1°	0°	′

Natural Cosines.

NATURAL TANGENTS.

′	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	′
0	000000	017455	034921	052408	069927	087489	105104	122785	140541	158384	60
5	1454	8910	6377	3866	071389	8954	6575	4261	2024	9876	55
10	2909	020365	7834	5325	2851	090421	8046	5738	3508	161368	50
15	4363	1820	9290	6784	4313	1887	9518	7216	4993	2860	45
20	5818	3275	040747	8243	5775	3354	110990	8694	6478	4354	40
25	7272	4731	2204	9703	7238	4821	2463	130173	7964	5848	35
30	8727	6186	3661	061163	8702	6289	3936	1652	9451	7343	30
35	010181	7641	5118	2623	080165	7757	5409	3132	150938	8838	25
40	1636	9097	6576	4083	1629	9226	6883	4613	2426	170334	20
45	3091	030553	8033	5543	3094	100695	8358	6094	3915	1831	15
50	4545	2009	9491	7004	4558	2164	9833	7576	5404	3329	10
55	6000	3465	050949	8465	6023	3634	121309	9058	5894	4828	5
60	7455	4921	2408	9927	7489	5104	2785	140541	8384	6327	0
Cot.	89°	88°	87°	86°	85°	84°	83°	82°	81°	80°	

Tan.	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	
0	176327	194380	212557	230868	249328	267949	286745	305731	324920	344328	60
5	7827	5890	4077	2401	250873	9509	8320	7322	6528	5955	55
10	9328	7401	5599	3934	2420	271069	9896	8914	8139	7585	50
15	180830	8912	7121	5469	3968	2631	291473	310508	9751	9216	45
20	2332	200425	8645	7004	5517	4194	3052	2104	331364	350848	40
25	3835	1938	220169	8541	7066	5759	4632	3701	2979	2483	35
30	5339	3452	1695	240079	8618	7325	6214	5299	4595	4119	30
35	6844	4967	3221	1618	260170	8892	7796	6899	6213	5756	25
40	8350	6483	4749	3157	1723	280460	9380	8500	7833	7396	20
45	9856	8000	6277	4698	3278	2029	300966	320103	9454	9037	15
50	191363	9518	7806	6241	4834	3600	2553	1707	341077	360680	10
55	2871	211037	9337	7784	6391	5172	4141	3313	2702	2324	5
60	4380	2557	230868	9328	7949	6745	5731	4920	4328	3970	0
Cot.	79°	78°	77°	76°	75°	74°	73°	72°	71°	70°	

Tan.	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	
0	363970	383864	404026	424475	445229	466308	487733	509525	531709	554309	60
5	5618	5534	5719	6192	6973	8080	9534	511349	3577	6212	55
10	7268	7205	7414	7912	8719	9854	491339	3195	5447	8118	50
15	8920	8879	9111	9634	450467	471631	3145	5034	7319	560027	45
20	370573	390554	410810	431358	2218	3410	4955	6876	9195	1939	40
25	2228	2231	2511	3084	3971	5195	6767	8720	541074	3854	35
30	3885	3910	4214	4812	5726	6976	8582	520567	2956	5773	30
35	5543	5592	5919	6543	7484	8762	500399	2417	4840	7694	25
40	7204	7275	7626	8276	9244	480551	2219	4270	6728	9619	20
45	8866	8960	9335	440011	461006	2343	4042	6126	8619	571547	15
50	380530	400646	421046	1748	2771	4137	5867	7984	550513	3478	10
55	2196	2335	2759	3487	4538	5933	7695	9845	2409	5413	5
60	3864	4026	4475	5229	6308	7733	9525	531709	4309	7350	0
′	69°	68°	67°	66°	65°	64°	63°	62°	61°	60°	′

Natural Cotangents.

Natural Tangents.

′	30°	31°	32°	33°	34°	35°	36°	37°	′
0	577350	600861	624869	649408	674509	700208	726543	753554	60
5	9291	2842	6894	651477	6627	2377	8767	5837	55
10	581235	4827	8921	3551	8749	4551	730996	8125	50
15	3183	6815	630953	5629	680876	6730	3230	760418	45
20	5134	8807	2988	7710	3007	8913	5469	2716	40
25	7088	610802	5027	9796	5142	711101	7713	5019	35
30	9045	2801	7070	661886	7281	3293	9961	7327	30
35	591006	4803	9117	3979	9425	5430	742214	9640	25
40	2970	6809	641167	6077	691572	7691	4472	771959	20
45	4938	8819	3222	8179	3725	9897	6735	4283	15
50	6908	620832	5280	670285	5881	722108	9003	6612	10
55	8883	2849	7342	2394	8042	4323	751276	8946	5
60	600861	4869	9408	4509	700208	6543	3554	781286	0
Cot.	59°	58°	57°	56°	55°	54°	53°	52°	

Tan.	38°	39°	40°	41°	42°	43°	44°	45°	
0	781286	809784	839100	869287	900404	932515	965689	1·000000	60
5	3631	812195	841581	871844	3041	5238	8504	002913	55
10	5981	4612	4069	4407	5685	7968	971326	005835	50
15	8336	7034	6563	6977	8336	940706	4157	008765	45
20	790698	9463	9062	9553	910994	3451	6996	011704	40
25	3064	821897	851568	882136	3659	6204	9842	014651	35
30	5436	4336	4081	4725	6331	8965	982697	017607	30
35	7813	6782	6599	7322	9010	951733	5560	020572	25
40	800196	9234	9124	9924	921697	4508	8432	023546	20
45	2585	831691	861655	892534	4391	7292	991311	026529	15
50	4979	4155	4193	5151	7091	960083	4199	029520	10
55	7379	6624	6736	7774	9809	2882	7095	032521	5
60	9784	9100	9287	900404	932515	5689	1·000000	035530	0
Cot.	51°	50°	49°	48°	47°	46°	45°	44°	

Tan.	46°	47°	48°	49°	50°	51°	52°	53°	
0	1·035530	1·072369	1·110613	1·150368	1·191754	1·234897	1·279942	1·327045	60
5	038549	075501	113866	153753	195280	238576	283786	331068	55
10	041577	078642	117131	157150	198818	242269	287645	335108	50
15	044614	081794	120405	160557	202360	245974	291518	339162	45
20	047660	084955	123691	163076	205933	249693	295406	343233	40
25	050715	088127	126987	167407	209509	253426	299308	347320	35
30	053780	091309	130294	170850	213097	257172	303225	351422	30
35	056854	094500	133612	174304	216698	260932	307158	355541	25
40	059938	097702	136941	177770	220312	264706	311105	359676	20
45	063031	100914	140282	181248	223939	268494	315067	363828	15
50	066134	104137	143633	184738	227579	272296	319044	367996	10
55	069247	107369	146995	188240	231231	276112	323037	372181	5
60	072369	110613	150368	191754	234897	279942	327045	376382	0
Cot.	43°	42°	41°	40°	39°	38°	37°	36°	

Tan.	54°	55°	56°	57°	58°	59°	60°	61°	
0	1·376382	1·428148	1·482561	1·539865	1·600335	1·664280	1·732051	1·804048	60
5	380600	432578	487222	544779	605526	669776	737883	810252	55
10	384835	437027	491904	549716	610742	675299	743745	816489	50
15	389088	441494	496606	554674	615982	680849	749637	822759	45
20	393357	445980	501328	559655	621247	686426	755559	829063	40
25	397644	450485	506071	564659	626537	692031	761511	835400	35
30	401948	455009	510835	569686	631852	697663	767494	841771	30
35	406270	459552	515620	574735	637192	703323	773508	848176	25
40	410610	464115	520426	579808	642558	709012	779552	854616	20
45	414967	468697	525254	584904	647949	714728	785629	861091	15
50	419343	473298	530102	590024	653366	720474	791736	867600	10
55	423736	477920	534973	595167	658810	826248	797876	874146	5
60	428148	482561	539865	600335	664280	732051	804048	880727	0
′	35°	34°	33°	32°	31°	30°	29°	28°	′

Natural Cotangents.

Distance.	¼ Deg.		½ Deg.		¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	1·00	0·00	1·00	0·01	1·00	0·01	1
2	2·00	0·01	2·00	0·02	2·00	0·03	2
3	3·00	0·01	3·00	0·03	3·00	0·04	3
4	4·00	0·02	4·00	0·03	4·00	0·05	4
5	5·00	0·02	5·00	0·04	5·00	0·07	5
6	6·00	0·03	6·00	0·05	6·00	0·08	6
7	7·00	0·03	7·00	0·06	7·00	0·09	7
8	8·00	0·03	8·00	0·07	8·00	0·10	8
9	9·00	0·04	9·00	0·08	9·00	0·12	9
10	10·00	0·04	10·00	0·09	10·00	0·13	10
11	11·00	0·05	11·00	0·10	11·00	0·14	11
12	12·00	0·05	12·00	0·10	12·00	0·16	12
13	13·00	0·06	13·00	0·11	13·00	0·17	13
14	14·00	0·06	14·00	0·12	14·00	0·18	14
15	15·00	0·07	15·00	0·13	15·00	0·20	15
16	16·00	0·07	16·00	0·14	16·00	0·21	16
17	17·00	0·07	17·00	0·15	17·00	0·22	17
18	18·00	0·08	18·00	0·16	18·00	0·24	18
19	19·00	0·08	19·00	0·17	19·00	0·25	19
20	20·00	0·09	20·00	0·17	20·00	0·26	20
21	21·00	0·09	21·00	0·18	21·00	0·27	21
22	22·00	0·10	22·00	0·19	22·00	0·29	22
23	23·00	0·10	23·00	0·20	23·00	0·30	23
24	24·00	0·10	24·00	0·21	24·00	0·31	24
25	25·00	0·11	25·00	0·22	25·00	0·33	25
26	26·00	0·11	26·00	0·23	26·00	0·34	26
27	27·00	0·12	27·00	0·24	27·00	0·35	27
28	28·00	0·12	28·00	0·24	28·00	0·37	28
29	29·00	0·13	29·00	0·25	29·00	0·38	29
30	30·00	0·13	30·00	0·26	30·00	0·39	30
31	31·00	0·14	31·00	0·27	31·00	0·41	31
32	32·00	0·14	32·00	0·28	32·00	0·42	32
33	33·00	0·14	33·00	0·29	33·00	0·43	33
34	34·00	0·15	34·00	0·30	34·00	0·45	34
35	35·00	0·15	35·00	0·31	35·00	0·46	35
36	36·00	0·16	36·00	0·31	36·00	0·47	36
37	37·00	0·16	37·00	0·32	37·00	0·48	37
38	38·00	0·17	38·00	0·33	38·00	0·50	38
39	39·00	0·17	39·00	0·34	39·00	0·51	39
40	40·00	0·17	40·00	0·35	40·00	0·52	40
41	41·00	0·18	41·00	0·36	41·00	0·54	41
42	42·00	0·18	42·00	0·37	42·00	0·55	42
43	43·00	0·19	43·00	0·38	43·00	0·56	43
44	44·00	0·19	44·00	0·38	44·00	0·58	44
45	45·00	0·20	45·00	0·39	45·00	0·59	45
46	46·00	0·20	46·00	0·40	46·00	0·60	46
47	47·00	0·21	47·00	0·41	47·00	0·62	47
48	48·00	0·21	48·00	0·42	48·00	0·63	48
49	49·00	0·21	49·00	0·43	49·00	0·64	49
50	50·00	0·22	50·00	0·44	50·00	0·65	50
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
Distance.	89¾ Deg.		89½ Deg.		89¼ Deg.		Distance.

Distance.	¼ Deg.		½ Deg.		¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	51·00	0·22	51·00	0·45	51·00	0·67	51
52	52·00	0·23	52·00	0·45	52·00	0·68	52
53	53·00	0·23	53·00	0·46	53·00	0·69	53
54	54·00	0·24	54·00	0·47	54·00	0·71	54
55	55·00	0·24	55·00	0·48	55·00	0·72	55
56	56·00	0·24	56·00	0·49	56·00	0·73	56
57	57·00	0·25	57·00	0·50	57·00	0·75	57
58	58·00	0·25	58·00	0·51	57·99	0·76	58
59	59·00	0·26	59·00	0·51	58·99	0·77	59
60	60·00	0·26	60·00	0·52	59·99	0·79	60
61	61·00	0·27	61·00	0·53	60·99	0·80	61
62	62·00	0·27	62·00	0·54	61·99	0·81	62
63	63·00	0·27	63·00	0·55	62·99	0·82	63
64	64·00	0·28	64·00	0·56	63·99	0·84	64
65	65·00	0·28	65·00	0·57	64·99	0·85	65
66	66·00	0·29	66·00	0·58	65·99	0·86	66
67	67·00	0·29	67·00	0·58	66·99	0·88	67
68	68·00	0·30	68·00	0·59	67·99	0·89	68
69	69·00	0·30	69·00	0·60	68·99	0·90	69
70	70·00	0·31	70·00	0·61	69·99	0·92	70
71	71·00	0·31	71·00	0·62	70·99	0·93	71
72	72·00	0·31	72·00	0·63	71·99	0·94	72
73	73·00	0·32	73·00	0·64	72·99	0·96	73
74	74·00	0·32	74·00	0·65	73·99	0·97	74
75	75·00	0·33	75·00	0·65	74·99	0·98	75
76	76·00	0·33	76·00	0·66	75·99	0·99	76
77	77·00	0·34	77·00	0·67	76·99	1·01	77
78	78·00	0·34	78·00	0·68	77·99	1·02	78
79	79·00	0·34	79·00	0·69	78·99	1·03	79
80	80·00	0·35	80·00	0·70	79·99	1·05	80
81	81·00	0·35	81·00	0·71	80·99	1·06	81
82	82·00	0·36	82·00	0·72	81·99	1·07	82
83	83·00	0·36	83·00	0·72	82·99	1·09	83
84	84·00	0·37	84·00	0·73	83·99	1·10	84
85	85·00	0·37	85·00	0·74	84·99	1·11	85
86	86·00	0·38	86·00	0·75	85·99	1·13	86
87	87·00	0·38	87·00	0·76	86·99	1·14	87
88	88·00	0·38	88·00	0·77	87·99	1·15	88
89	89·00	0·39	89·00	0·78	88·99	1·16	89
90	90·00	0·39	90·00	0·79	89·99	1·18	90
91	91·00	0·40	91·00	0·79	90·99	1·19	91
92	92·00	0·40	92·00	0·80	91·99	1·20	92
93	93·00	0·41	93·00	0·81	92·99	1·22	93
94	94·00	0·41	94·00	0·82	93·99	1·23	94
95	95·00	0·41	95·00	0·83	94·99	1·24	95
96	96·00	0·42	96·90	0·84	95·99	1·26	96
97	97·00	0·42	97·00	0·85	96·99	1·27	97
98	98·00	0·43	98·00	0·86	97·99	1·28	98
99	99·00	0·43	99·00	0·86	98·99	1·30	99
100	100·00	0·44	100·00	0·87	99·99	1·31	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	89¾ Deg.		89½ Deg.		89¼ Deg.		

Distance.	1 Deg.		1¼ Deg.		1½ Deg.		1¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	1·00	0·02	1·00	0·02	1·00	0·03	1·00	0·03	1
2	2·00	0·03	2·00	0·04	2·00	0·05	2·00	0·06	2
3	3.00	0·05	3·00	0·07	3·00	0·08	3·00	0·09	3
4	4·00	0·07	4·00	0·09	4·00	0·10	4·00	0·12	4
5	5·00	0·09	5·00	0·11	5·00	0·13	5·00	0·15	5
6	6·00	0·10	6·00	0·13	6·00	0·16	6·00	0·18	6
7	7·00	0·12	7·00	0·15	7·00	0·18	7·00	0·21	7
8	8·00	0·14	8·00	0·17	8·00	0·21	8·00	0·25	8
9	9·00	0·16	9·00	0·20	9·00	0·24	9·00	0·28	9
10	10·00	0·17	10·00	0·22	10·00	0·26	10·00	0·31	10
11	11·00	0·19	11·00	0·24	11·00	0·28	10·99	0·34	11
12	12·00	0·21	12·00	0·26	12·00	0·31	11·99	0·37	12
13	13·00	0·23	13·00	0·28	13·00	0·34	12·99	0·40	13
14	14·00	0·24	14·00	0·31	14·00	0·37	13·99	0·43	14
15	15·00	0·26	15·00	0·33	14·99	0·39	14·99	0·46	15
16	16·00	0·28	16·00	0·35	15·99	0·42	15·99	0·49	16
17	17·00	0·30	17·00	0·37	16·99	0·45	16·99	0·52	17
18	18·00	0·31	18·00	0·39	17·99	0·47	17·99	0·55	18
19	19·00	0·33	19·00	0·41	18·99	0·50	18·99	0·58	19
20	20·00	0·35	20·00	0·44	19·99	0·52	19·99	0·61	20
21	21·00	0·37	21·00	0·46	20·99	0·55	20·99	0·64	21
22	22·00	0·38	21·99	0·48	21·99	0·58	21·99	0·67	22
23	23·00	0·40	22·99	0.50	22·99	0·60	22·99	0·70	23
24	24·00	0·42	23·99	0·52	23·99	0·63	23·99	0·73	24
25	25·00	0·44	24·99	0·55	24·99	0·65	24·99	0·76	25
26	26·00	0·45	25·99	0·57	25·99	0·68	25·99	0·79	26
27	27·00	0·47	26·99	0·59	26·99	0·71	26·99	0·83	27
28	28·00	0·49	27·99	0·61	27·99	0·73	27·99	0·86	28
29	29·00	0·51	28·99	0·63	28·99	0·76	28·99	0·89	29
30	30·00	0·52	29·99	0·65	29·99	0·79	29·99	0·92	30
31	31·00	0·54	30·99	0·68	30·99	0·81	30·99	0·95	31
32	32·00	0·56	31·99	0·70	31·99	0·84	31·99	0·98	32
33	32·99	0.58	32·99	0·72	32·99	0·86	32·98	1·01	33
34	33·99	0·59	33·99	0·74	33·99	0·89	33·98	1·04	34
35	34·99	0·61	34·99	0·76	34·99	0·92	34·98	1·07	35
36	35·99	0·63	35·99	0·79	35·99	0·94	35·98	1·10	36
37	36·99	0·65	36·99	0·81	36·99	0·97	36·98	1·13	37
38	37·99	0·66	37·99	0·83	37·99	0·99	37·98	1·16	38
39	38·99	0·68	38·99	0·85	38·99	1·02	38·98	1·19	39
40	39·99	0·70	39·99	0·87	39·99	1·05	39·98	1·22	40
41	40·99	0·72	40·99	0·89	40·99	1·07	40·98	1·25	41
42	41·99	0·73	41·99	0·92	41·99	1·10	41·98	1·28	42
43	42·99	0·75	42·99	0·94	42·99	1·13	42·98	1·31	43
44	43·99	0·77	43·99	0·96	43·99	1·15	43·98	1·34	44
45	44·99	0·79	44·99	0·98	44·99	1·18	44·98	1·37	45
46	45·99	0·80	45·99	1·00	45·99	1·20	45·98	1·40	46
47	46·99	0·82	46·99	1·03	46·99	1·23	46·98	1·44	47
48	47·99	0·84	47·99	1·05	47·98	1·26	47·98	1·47	48
49	48·99	0·86	48·99	1·07	48·98	1·28	48·98	1·50	49
50	49·99	0·87	49·99	1·09	49·98	1·31	49·98	1·53	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	89 Deg.		88¾ Deg.		88½ Deg.		88¼ Deg.		

Distance.	1 Deg.		1¼ Deg.		1½ Deg.		1¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	50·99	0·89	50·99	1·11	50·98	1·34	50·98	1·56	51
52	51·99	0·91	51·99	1·13	51·98	1·36	51·98	1·59	52
53	52·99	0·92	52·99	1·16	52·98	1·39	52·98	1·62	53
54	53·99	0·94	53·99	1·18	53·98	1·41	53·97	1·65	54
55	54·99	0·96	54·99	1·20	54·98	1·44	54·97	1·68	55
56	55·99	0·98	55·99	1·22	55·98	1·47	55·97	1·71	56
57	56·99	0·99	56·99	1·24	56·98	1·49	56·97	1·74	57
58	57·99	1·01	57·99	1·27	57·98	1·52	57·97	1·77	58
59	58·99	1·03	58·99	1·29	58·98	1·54	58·97	1·80	59
60	59·99	1·05	59·99	1·31	59·98	1·57	59·97	1·83	60
61	60·99	1·06	60·99	1·33	60.98	1·60	60·97	1·86	61
62	61·99	1·08	61·99	1·35	61·98	1·62	61·97	1·89	62
63	62·99	1·10	62·99	1·37	62·98	1·65	62·97	1·92	63
64	63·99	1·12	63·98	1·40	63·98	1·68	63·97	1·95	64
65	64·99	1·13	64·98	1·42	64·98	1·70	64·97	1·99	65
66	65·99	1·15	65·98	1·44	65·98	1·73	65·97	2·02	66
67	66·99	1·17	66·98	1·46	66·98	1·75	66·97	2·05	67
68	67·99	1·19	67·98	1·48	67·98	1·78	67·97	2·08	68
69	68·99	1·20	68·98	1·51	68·98	1·81	68·97	2·11	69
70	69·99	1·22	69·98	1·53	69·98	1·83	69·97	2·14	70
71	70·99	1·24	70·98	1·55	70·98	1·86	70·97	2·17	71
72	71·99	1·26	71·98	1·57	71·98	1·88	71·97	2·20	72
73	72·99	1·27	72·98	1·59	72·97	1·91	72·97	2·23	73
74	73·99	1·29	73·98	1·61	73·97	1·94	73·97	2·26	74
75	74·99	1.31	74·98	1·64	74·97	1·96	74·97	2·29	75
76	75·99	1·33	75·98	1·66	75·97	1·99	75·96	2·32	76
77	76·99	1·34	76·98	1·68	76·97	2·02	76·96	2·35	77
78	77·99	1·36	77·98	1·70	77·97	2·04	77·96	2·38	78
79	78·99	1·38	78·98	1·72	78·97	2·07	78·96	2·41	79
80	79·99	1·40	79·98	1·75	79·97	2·09	79·96	2·44	80
81	80·99	1·41	80·98	1·77	80·97	2·12	80·96	2·47	81
82	81·99	1·43	81·98	1·79	81·97	2·15	81·96	2·50	82
83	82·99	1·45	82·98	1·81	82·97	2·17	82·96	2·53	83
84	83·99	1·47	83·98	1·83	83·97	2·20	83·96	2·57	84
85	84·99	1·48	84·98	1·85	84·97	2·23	84·96	2·60	85
86	85·99	1·50	85·98	1·88	85·97	2·25	85·96	2·63	86
87	86·99	1·52	86·98	1·90	86.97	2·28	86·96	2·66	87
88	87·99	1·54	87·98	1·92	87·97	2·30	87·96	2·69	88
89	88·99	1·55	88·98	1·94	88·97	2·33	88·96	2·72	89
90	89·99	1·57	89·98	1·96	89·97	2·36	89·96	2·75	90
91	90·99	1·59	90·98	1·99	90·97	2·38	90·96	2·78	91
92	91·99	1·61	91·98	2·01	91·97	2·41	91·96	2·81	92
93	92·99	1·62	92·98	2·03	92·97	2·43	92·96	2·84	93
94	93·99	1·64	93·98	2·05	93·97	2·46	93·96	2·87	94
95	94·99	1·66	94·98	2·07	94·97	2·49	94·96	2·90	95
96	95·99	1·68	95·98	2·09	95·97	2·51	95·96	2·94	96
97	96·99	1·69	96·98	2·12	96·97	2·54	96·95	2·96	97
98	97·99	1·71	97·98	2·14	97·97	2·57	97·95	2·99	98
99	98·98	1·73	98·98	2·16	98·97	2·59	98·95	3·02	99
100	99·98	1·75	99·98	2·18	99·97	2·62	99·95	3·05	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	89 Deg.		88¾ Deg.		88½ Deg.		88¼ Deg.		

Distance.	2 Deg. Lat.	2 Deg. Dep.	2¼ Deg. Lat.	2¼ Deg. Dep.	2½ Deg. Lat.	2½ Deg. Dep.	2¾ Deg. Lat.	2¾ Deg. Dep.	Distance.
1	1·00	0·03	1·00	0·04	1·00	0·04	1·00	0·05	1
2	2·00	0·07	2·00	0·08	2·00	0·09	2·00	0·10	2
3	3·00	0·10	3·00	0·12	3·00	0·13	3·00	0·14	3
4	4·00	0·14	4·00	0·16	4·00	0·17	4·00	0·19	4
5	5·00	0·17	5·00	0·20	5·00	0·22	4·99	0·24	5
6	6·00	0·21	6·00	0·24	5·99	0·26	5·99	0·29	6
7	7·00	0·24	6·99	0·27	6·99	0·31	6·99	0·34	7
8	7·99	0·28	7·99	0·31	7·99	0·35	7·99	0·38	8
9	8·99	0·31	8·99	0·35	8·99	0·39	8·99	0·43	9
10	9·99	0·35	9·99	0·39	9·99	0·44	9·99	0·48	10
11	10·99	0·38	10·99	0·43	10·99	0·48	10·99	0·53	11
12	11·99	0·42	11·99	0·47	11·99	0·52	11·99	0·58	12
13	12·99	0·45	12·99	0·51	12·99	0·57	12·99	0·62	13
14	13·99	0·49	13·99	0·55	13·99	0·61	13·98	0·67	14
15	14·99	0·52	14·99	0·59	14·99	0·65	14·98	0·72	15
16	15·99	0·56	15·99	0·63	15·99	0·70	15·98	0·77	16
17	16·99	0·59	16·99	0·67	16·98	0·74	16·98	0·82	17
18	17·99	0·63	17·99	0·71	17·98	0·79	17·98	0·86	18
19	18·99	0·66	18·99	0·75	18·98	0·83	18·98	0·91	19
20	19·99	0·70	19·98	0·79	19·98	0·87	19·98	0·96	20
21	20·99	0·73	20·98	0·82	20·98	0·92	20·98	1·01	21
22	21·99	0·77	21·98	0·86	21·98	0·96	21·97	1·06	22
23	22·99	0·80	22·98	0·90	22·98	1·00	22·97	1·10	23
24	23·99	0·84	23·98	0·94	23·98	1·05	23·97	1·15	24
25	24·98	0·87	24·98	0·98	24·98	1·09	24·97	1·20	25
26	25·98	0·91	25·98	1·02	25·98	1·13	25·97	1·25	26
27	26·98	0·94	26·98	1·06	26·97	1·18	26·97	1·30	27
28	27·98	0·98	27·98	1·10	27·97	1·22	27·97	1·34	28
29	28·98	1·01	28·98	1·14	28·97	1·26	28·97	1·39	29
30	29·98	1·05	29·98	1·18	29·97	1·31	29·97	1·44	30
31	30·98	1·08	30·98	1·22	30·97	1·35	30·96	1·49	31
32	31·98	1·12	31·98	1·26	31·97	1·40	31·96	1·54	32
33	32·98	1·15	32·97	1·30	32·97	1·44	32·96	1·58	33
34	33·98	1·19	33·97	1·33	33·97	1·48	33·96	1·63	34
35	34·98	1·22	34·97	1·37	34·97	1·53	34·96	1·68	35
36	35·98	1·26	35·97	1·41	35·97	1·57	35·96	1·73	36
37	36·98	1·29	36·97	1·45	36·96	1·61	36·96	1·78	37
38	37·98	1·33	37·97	1·49	37·96	1·66	37·96	1·82	38
39	38·98	1·36	38·97	1·53	38·96	1·70	38·96	1·87	39
40	39·98	1·40	39·97	1·57	39·96	1·75	39·95	1·92	40
41	40·98	1·43	40·97	1·61	40·96	1·77	40·95	1·97	41
42	41·97	1·47	41·97	1·65	41·96	1·83	41·95	2·02	42
43	42·97	1·50	42·97	1·69	42·96	1·88	42·95	2·06	43
44	43·97	1·54	43·97	1·73	43·96	1·92	43·95	2·11	44
45	44·97	1·57	44·97	1·77	44·96	1·96	44·95	2·16	45
46	45·97	1·61	45·96	1·81	45·96	2·01	45·95	2·21	46
47	46·97	1·64	46·96	1·85	46·96	2·05	46·95	2·25	47
48	47·97	1·68	47·96	1·88	47·95	2·09	47·95	2·30	48
49	48·97	1·71	48·96	1·92	48·95	2·14	48·94	2·35	49
50	49·97	1·74	49·96	1·96	49·95	2·18	49·94	2·40	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	88 Deg.		87¾ Deg.		87½ Deg.		87¼ Deg.		

Distance.	2 Deg.		2¼ Deg.		2½ Deg.		2¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	50·97	1·78	50·96	2·00	50·95	2·22	50·94	2·45	51
52	51·97	1·81	51·96	2·04	51·95	2·27	51·94	2·50	52
53	52·97	1·85	52·96	2·08	52·95	2·31	52·94	2·54	53
54	53·97	1·88	53·96	2·12	53·95	2·36	53·94	2·59	54
55	54·97	1·92	54·96	2·16	54·95	2·40	54·94	2·64	55
56	55·97	1·95	55·96	2·20	55·95	2·44	55·94	2·69	56
57	56·97	1·99	56·96	2·24	56·95	2·49	56·93	2·73	57
58	57·96	2·02	57·96	2·28	57·94	2·53	57·93	2·78	58
59	58·96	2·06	58·95	2·32	58·94	2·57	58·93	2·83	59
60	59·96	2·09	59·95	2·36	59·94	2·62	59·93	2·88	60
61	60·96	2·13	60·95	2·39	60·94	2·66	60·93	2·93	61
62	61·96	2·16	61·95	2·43	61·94	2·70	61·93	2·97	62
63	62·96	2·20	62·95	2·47	62·94	2·75	62·93	3·02	63
64	63·96	2·23	63·95	2·51	63·94	2·79	63·93	3·07	64
65	64·96	2·27	64·95	2·55	64·94	2·84	64·93	3·12	65
66	65·96	2·30	65·95	2·59	65·94	2·88	65·92	3·17	66
67	66·96	2·34	66·95	2·63	66·94	2·92	66·92	3·21	67
68	67·96	2·37	67·95	2·67	67·94	2·97	67·92	3·26	68
69	68·96	2·41	68·95	2·71	68·93	3·01	68·92	3·31	69
70	69·96	2·44	69·95	2·75	69·93	3·05	69·92	3·36	70
71	70·96	2·48	70·95	2·79	70·93	3·10	70·92	3·41	71
72	71·96	2·51	71·94	2·83	71·93	3·14	71·92	3·45	72
73	72·96	2·55	72·94	2·87	72·93	3·18	72·92	3·50	73
74	73·95	2·58	73·94	2·91	73·93	3·23	73·91	3·55	74
75	74·95	2·62	74·94	2·94	74·93	3·27	74·91	3·60	75
76	75·95	2·65	75·94	2·98	75·93	3·31	75·91	3·65	76
77	76·95	2·69	76·94	3·02	76·93	3·36	76·91	3·70	77
78	77·95	2·72	77·94	3·06	77·93	3·40	77·91	3·74	78
79	78·95	2·76	78·94	3·10	78·92	3·45	78·91	3·79	79
80	79·95	2·79	79·94	3·14	79·92	3·49	79·91	3·84	80
81	80·95	2·83	80·94	3·18	80·92	3·53	80·91	3·89	81
82	81·95	2·86	81·94	3·22	81·92	3·58	81·91	3·93	82
83	82·95	2·90	82·94	3·26	82·92	3·62	82·90	3·98	83
84	83·95	2·93	83·94	3·30	83·92	3·66	83·90	4·03	84
85	84·95	2·97	84·93	3·34	84·92	3·71	84·90	4·08	85
86	85·95	3·00	85·93	3·38	85·92	3·75	85·90	4·13	86
87	86·95	3·04	86·93	3·42	86·92	3·79	86·90	4·17	87
88	87·95	3·07	87·93	3·45	87·92	3·84	87·90	4·22	88
89	88·95	3·11	88·93	3·49	88·92	3·88	88·90	4·27	89
90	89·95	3·14	89·93	3·53	89·91	3·93	89·90	4·32	90
91	90·95	3·18	90·93	3·57	90·91	3·97	90·90	4·37	91
92	91·94	3·21	91·93	3·61	91·91	4·01	91·89	4·41	92
93	92·94	3·25	92·93	3·65	92·91	4·06	92·89	4·46	93
94	93·94	3·28	93·93	3·69	93·91	4·10	93·89	4·51	94
95	94·94	3·32	94·93	3·73	94·91	4·14	94·89	4·56	95
96	95·94	3·35	95·93	3·77	95·91	4·19	95·89	4·61	96
97	96·94	3·39	96·93	3·81	96·91	4·23	96·89	4·65	97
98	97·94	3·42	97·92	3·85	97·91	4·27	97·89	4·70	98
99	98·94	3·46	98·92	3·89	98·91	4·32	98·89	4·75	99
100	99·94	3·49	99·92	3·93	99·91	4·36	99·88	4·80	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	88 Deg.		87¾ Deg.		87½ Deg.		87¼ Deg.		

Distance.	3 Deg.		3¼ Deg.		3½ Deg.		3¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	1·00	0·05	1·00	0·06	1·00	0·06	1·00	0·06	1
2	2·00	0·10	2·00	0·11	2·00	0·12	2·00	0·13	2
3	3·00	0·16	3·00	0·17	2·99	0·18	2·99	0·20	3
4	3·99	0·21	3·99	0·23	3·99	0·24	3·99	0·26	4
5	4·99	0·26	4·99	0·28	4·99	0·31	4·99	0·33	5
6	5·99	0·31	5·99	0·34	5·99	0·37	5·99	0·39	6
7	6·99	0·37	6·99	0·40	6·99	0·43	6·99	0·46	7
8	7·99	0·42	7·99	0·45	7·99	0·49	7·98	0·52	8
9	8·99	0·47	8·99	0·51	8·98	0·55	8·98	0·59	9
10	9·99	0·52	9·98	0·57	9·98	0·61	9·98	0·65	10
11	10·98	0·58	10·98	0·62	10·98	0·67	10·98	0·72	11
12	11·98	0·63	11·98	0·68	11·98	0·73	11·97	0·78	12
13	12·98	0·68	12·98	0·73	12·98	0·79	12·97	0·85	13
14	13·98	0·73	13·98	0·79	13·97	0·85	13·97	0·92	14
15	14·98	0·79	14·98	0·85	14·97	0·92	14·97	0·98	15
16	15·98	0·84	15·97	0·91	15·97	0·98	15·97	1·05	16
17	16·98	0·89	16·97	0·96	16·97	1·04	16·96	1·11	17
18	17·98	0·94	17·97	1·02	17·97	1·10	17·96	1·18	18
19	18·98	0·99	18·97	1·08	18·96	1·16	18·96	1·24	19
20	19·97	1·05	19·97	1·13	19·96	1·22	19·96	1·31	20
21	20·97	1·10	20·97	1·19	20·96	1·28	20·96	1·37	21
22	21·97	1·15	21·96	1·25	21·96	1·34	21·95	1·44	22
23	22·97	1·20	22·96	1·30	22·96	1·40	22·95	1·50	23
24	23·97	1·26	23·96	1·36	23·96	1·47	23·95	1·57	24
25	24·97	1·31	24·96	1·42	24·95	1·53	24·95	1·64	25
26	25·96	1·36	25·96	1·47	25·95	1·59	25·94	1·70	26
27	26·96	1·41	26·96	1·53	26·95	1·65	26·94	1·77	27
28	27·96	1·47	27·95	1·59	27·95	1·71	27·94	1·83	28
29	28·96	1·52	28·95	1·64	28·95	1·77	28·94	1·90	29
30	29·96	1·57	29·95	1·70	29·94	1·83	29·94	1·96	30
31	30·96	1·62	30·95	1·76	30·94	1·89	30·93	2·03	31
32	31·96	1·67	31·95	1·81	31·94	1·95	31·93	2·09	32
33	32·95	1·73	32·95	1·87	32·94	2·01	32·93	2·16	33
34	33·95	1·78	33·95	1·93	33·94	2·08	33·93	2·22	34
35	34·95	1·83	34·94	1·98	34·93	2·14	34·92	2·29	35
36	35·95	1·88	35·94	2·04	35·93	2·20	35·92	2·35	36
37	36·95	1·94	36·94	2·10	36·93	2·26	36·92	2·42	37
38	37·95	1·99	37·94	2·15	37·93	2·32	37·92	2·49	38
39	38·95	2·04	38·94	2·21	38·93	2·38	38·92	2·55	39
40	39·95	2·09	39·94	2·27	39·93	2·44	39·91	2·62	40
41	40·94	2·15	40·93	2·32	40·92	2·50	40·91	2·68	41
42	41·94	2·20	41·93	2·38	41·92	2·56	41·91	2·75	42
43	42·94	2·25	42·93	2·44	42·92	2·63	42·91	2·81	43
44	43·94	2·30	43·93	2·49	43·92	2·69	43·91	2·88	44
45	44·94	2·36	44·93	2·55	44·92	2·75	44·90	2·94	45
46	45·94	2·41	45·93	2·61	45·91	2·81	45·90	3·01	46
47	46·94	2·46	46·92	2·66	46·91	2·87	46·90	3·07	47
48	47·93	2·51	47·92	2·72	47·91	2·93	47·90	3·14	48
49	48·93	2·56	48·92	2·78	48·91	2·99	48·90	3·20	49
50	49·93	2·62	49·92	2·83	49·91	3·05	49·89	3·27	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	87 Deg.		86¾ Deg.		86½ Deg.		86¼ Deg.		

Distance.	3 Deg.		3¼ Deg.		3½ Deg.		3¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	50·93	2·67	50·92	2·89	50·90	3·11	50·89	3·34	51
52	51·93	2·72	51·92	2·95	51·90	3·17	51·89	3·40	52
53	52·93	2·77	52·91	3·00	52·90	3·24	52·89	3·47	53
54	53·93	2·83	53·91	3·06	53·90	3·30	53·88	3·53	54
55	54·92	2·88	54·91	3·12	54·90	3·36	54·88	3·60	55
56	55·92	2·93	55·91	3·17	55·90	3·42	55·88	3·66	56
57	56·92	2·98	56·91	3·23	56·89	3·48	56·88	3·73	57
58	57·92	3·04	57·91	3·39	57·89	3·54	57·88	3·79	58
59	58·92	3·09	58·91	3·34	58·89	3·60	58·87	3·86	59
60	59·92	3·14	59·90	3·40	59·89	3·66	59·87	3·92	60
61	60·92	3·19	60·90	3·46	60·89	3·72	60·87	3·99	61
62	61·92	3·24	61·90	3·51	61·88	3·79	61·87	4·06	62
63	62·91	3·30	62·90	3·57	62·88	3·85	62·87	4·12	63
64	63·91	3·35	63·90	3·63	63·88	3·91	63·86	4·19	64
65	64·91	3·40	64·90	3·69	64·88	3·97	64·86	4·25	65
66	65·91	3·45	65·89	3·74	65·88	4·03	65·86	4·32	66
67	66·91	3·51	66·89	3·80	66·88	4·09	66·86	4·38	67
68	67·91	3·56	67·89	3·86	67·87	4·15	67·85	4·45	68
69	68·91	3·61	68·89	3·91	68·87	4·21	68·85	4·51	69
70	69·90	3·66	69·89	3·97	69·87	4·27	69·85	4·58	70
71	70·90	3·72	70·89	4·03	70·87	4·33	70·85	4·64	71
72	71·90	3·77	71·88	4·08	71·87	4·40	71·85	4·71	72
73	72·90	3·82	72·88	4·14	72·86	4·46	72·84	4·77	73
74	73·90	3·87	73·88	4·20	73·86	4·52	73·84	4·84	74
75	74·90	3·93	74·88	4·25	74·86	4·58	74·84	4·91	75
76	75·90	3·98	75·88	4·31	75·86	4·64	75·84	4·97	76
77	76·89	4·03	76·88	4·37	76·86	4·70	76·84	5·04	77
78	77·89	4·08	77·87	4·42	77·85	4·76	77·83	5·10	78
79	78·89	4·13	78·87	4·48	78·85	4·82	78·83	5·17	79
80	79·89	4·19	79·87	4·54	79·85	4·88	79·83	5·23	80
81	80·89	4·24	80·87	4·59	80·85	4·94	80·83	5·30	81
82	81·89	4·29	81·87	4·65	81·85	5·01	81·82	5·36	82
83	82·89	4·34	82·87	4·71	82·85	5·07	82·82	5·43	83
84	83·88	4·40	83·86	4·76	83·84	5·13	83·82	5·49	84
85	84·88	4·45	84·86	4·82	84·84	5·19	84·82	5·56	85
86	85·88	4·50	85·86	4·88	85·84	5·25	85·82	5·62	86
87	86·88	4·55	86·86	4·93	86·84	5·31	86·81	5·69	87
88	87·88	4·61	87·86	4·99	87·84	5·37	87·81	5·76	88
89	88·88	4·66	88·86	5·05	88·83	5·43	88·81	5·82	89
90	89·88	4·71	89·86	5·10	89·83	5·49	89·81	5·89	90
91	90·88	4·76	90·85	5·16	90·83	5·56	90·81	5·95	91
92	91·87	4·81	91·85	5·22	91·83	5·62	91·80	6·02	92
93	92·87	4·87	92·85	5·27	92·83	5·68	92·80	6·08	93
94	93·87	4·92	93·85	5·33	93·82	5·74	93·80	6·15	94
95	94·87	4·97	94·85	5·39	94·82	5·80	94·80	6·21	95
96	95·87	5·02	95·85	5·44	95·82	5·86	95·79	6·28	96
97	96·87	5·08	96·84	5·50	96·82	5·92	96·79	6·34	97
98	97·87	5·13	97·84	5·56	97·82	5·98	97·79	6·41	98
99	98·86	5·18	98·84	5·61	98·82	6·04	98·79	6·47	99
100	99·86	5·23	99·84	5·67	99·81	6·10	99·79	6·54	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	87 Deg.		86¾ Deg.		86½ Deg.		86¼ Deg.		

Distance.	4 Deg.		4¼ Deg.		4½ Deg.		4¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	1·00	0·07	1·00	0·07	1·00	0·08	1·00	0·08	1
2	2·00	0·14	1·99	0·15	1·99	0·16	1·99	0·17	2
3	2·99	0·21	2·99	0·22	2·99	0·24	2·99	0·25	3
4	3·99	0·28	3·99	0·30	3·99	0·31	3·98	0·33	4
5	4·99	0·35	4·99	0·37	4·98	0·39	4·98	0·41	5
6	5·99	0·42	5·98	0·44	5·98	0·47	5·98	0·50	6
7	6·98	0·49	6·98	0·52	6·98	0·55	6·97	0·58	7
8	7·98	0·56	7·98	0·59	7·98	0·63	7·97	0·66	8
9	8·98	0·63	8·98	0·67	8·97	0·71	8·97	0·75	9
10	9·98	0·70	9·97	0·74	9·97	0·78	9·97	0·83	10
11	10·97	0·77	10·97	0·82	10·97	0·86	10·96	0·91	11
12	11·97	0·84	11·97	0·89	11·96	0·94	11·96	0·99	12
13	12·97	0·91	12·96	0·96	12·96	1·02	12·96	1·08	13
14	13·97	0·98	13·96	1·04	13·96	1·10	13·95	1·16	14
15	14·96	1·05	14·96	1·11	14·95	1·18	14·95	1·24	15
16	15·96	1·12	15·96	1·19	15·95	1·26	15·95	1·32	16
17	16·96	1·19	16·95	1·26	16·95	1·33	16·94	1·41	17
18	17·96	1·26	17·95	1·33	17·94	1·41	17·94	1·49	18
19	18·95	1·33	18·95	1·40	18·94	1·49	18·93	1·57	19
20	19·95	1·40	19·95	1·48	19·94	1·57	19·93	1·66	20
21	20·95	1·46	20·94	1·56	20·94	1·65	20·93	1·74	21
22	21·95	1·53	21·94	1·63	21·93	1·73	21·92	1·82	22
23	22·94	1·60	22·94	1·70	22·93	1·80	22·92	1·90	23
24	23·94	1·67	23·93	1·78	23·93	1·88	23·92	1·99	24
25	24·94	1·74	24·93	1·85	24·92	1·96	24·91	2·07	25
26	25·94	1·81	25·93	1·93	25·92	2·04	25·91	2·15	26
27	26·93	1·88	26·93	2·00	26·92	2·12	26·91	2·24	27
28	27·93	1·95	27·92	2·08	27·91	2·20	27·90	2·32	28
29	28·93	2·02	28·92	2·15	28·91	2·28	28·90	2·40	29
30	29·93	2·09	29·92	2·22	29·91	2·35	29·90	2·48	30
31	30·92	2·16	30·91	2·30	30·90	2·43	30·89	2·57	31
32	31·92	2·23	31·91	2·37	31·90	2·51	31·89	2·65	32
33	32·92	2·30	32·91	2·45	32·90	2·59	32·89	2·73	33
34	33·92	2·37	33·91	2·52	33·90	2·67	33·88	2·82	34
35	34·91	2·44	34·90	2·59	34·89	2·75	34·88	2·90	35
36	35·91	2·51	35·90	2·67	35·89	2·82	35·88	2·98	36
37	36·91	2·58	36·90	2·74	36·89	2·90	36·87	3·06	37
38	37·91	2·65	37·90	2·82	37·88	2·98	37·87	3·15	38
39	38·90	2·72	38·89	2·89	38·88	3·06	38·87	3·23	39
40	39·90	2·79	39·89	2·96	39·88	3·14	39·86	3·31	40
41	40·90	2·86	40·89	3·04	40·87	3·22	40·86	3·40	41
42	41·90	2·93	41·88	3·11	41·87	3·30	41·86	3·48	42
43	42·90	3·00	42·88	3·19	42·87	3·37	42·85	3·56	43
44	43·89	3·07	43·88	3·26	43·86	3·45	43·85	3·64	44
45	44·89	3·14	44·88	3·33	44·86	3·53	44·85	3·73	45
46	45·89	3·21	45·87	3·41	45·86	3·61	45·84	3·81	46
47	46·89	3·28	46·87	3·48	46·86	3·69	46·84	3·89	47
48	47·88	3·35	47·87	3·56	47·85	3·77	47·84	3·97	48
49	48·88	3·42	48·87	3·63	48·85	3·84	48·83	4·06	49
50	49·88	3·49	49·86	3·71	49·85	3·92	49·83	4·14	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	86 Deg.		85¾ Deg.		85½ Deg.		85¼ Deg.		

Distance.	4 Deg.		4¼ Deg.		4½ Deg.		4¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	50·88	3·56	50·86	3·78	50·84	4·00	50·82	4·22	51
52	51·87	3·63	51·86	3·85	51·84	4·08	51·82	4·31	52
53	52·87	3·70	52·85	3·93	52·84	4·16	52·82	4·39	53
54	53·87	3·77	53·85	4·00	53·83	4·24	53·81	4·47	54
55	54·87	3·84	54·85	4·08	54·83	4·32	54·81	4·55	55
56	55·86	3·91	55·85	4·15	55·83	4·39	55·81	4·64	56
57	56·86	3·98	56·84	4·22	56·82	4·47	56·80	4·72	57
58	57·86	4·05	57·84	4·30	57·82	4·55	57·80	4·80	58
59	58·86	4·12	58·84	4·37	58·82	4·63	58·80	4·89	59
60	59·85	4·19	59·84	4·45	59·82	4·71	59·79	4·97	60
61	60·85	4·26	60·83	4·52	60·81	4·79	60·79	5·05	61
62	61·85	4·32	61·83	4·59	61·81	4·86	61·79	5·13	62
63	62·85	4·39	62·83	4·67	62·81	4·94	62·78	5·22	63
64	63·84	4·46	63·82	4·74	63·80	5·02	63·78	5·30	64
65	64·84	4·53	64·82	4·82	64·80	5·10	64·78	5·38	65
66	65·84	4·60	65·82	4·89	65·80	5·18	65·77	5·47	66
67	66·84	4·67	66·82	4·97	66·79	5·26	66·77	5·55	67
68	67·83	4·74	67·81	5·04	67·79	5·34	67·77	5·63	68
69	68·83	4·81	68·81	5·11	68·79	5·41	68·76	5·71	69
70	69·83	4·88	69·81	5·19	69·78	5·49	69·76	5·80	70
71	70·83	4·95	70·80	5·26	70·78	5·57	70·76	5·88	71
72	71·82	5·02	71·80	5·34	71·78	5·65	71·75	5·96	72
73	72·82	5·09	72·80	5·41	72·77	5·73	72·75	6·04	73
74	73·82	5·16	73·80	5·48	73·77	5·81	73·75	6·13	74
75	74·82	5·23	74·79	5·56	74·77	5·88	74·74	6·21	75
76	75·81	5·30	75·79	5·63	75·77	5·96	75·74	6·29	76
77	76·81	5·37	76·79	5·71	76·76	6·04	76·74	6·38	77
78	77·81	5·44	77·79	5·78	77·76	6·12	77·73	6·46	78
79	78·81	5·51	78·78	5·85	78·76	6·20	78·73	6·54	79
80	79·81	5·58	79·78	5·93	79·75	6·28	79·73	6·62	80
81	80·80	5·65	80·78	6·00	80·75	6·36	80·72	6·71	81
82	81·80	5·72	81·78	6·08	81·75	6·43	81·72	6·79	82
83	82·80	5·79	82·77	6·15	82·74	6·51	82·71	6·87	83
84	83·80	5·86	83·77	6·23	83·74	6·59	83·71	6·96	84
85	84·79	5·93	84·77	6·30	84·74	6·67	84·71	7·04	85
86	85·79	6·00	85·76	6·37	85·73	6·75	85·70	7·12	86
87	86·79	6·07	86·76	6·45	86·73	6·83	86·70	7·20	87
88	87·79	6·14	87·76	6·52	87·73	6·90	87·70	7·29	88
89	88·78	6·21	88·76	6·60	88·73	6·98	88·70	7·37	89
90	89·78	6·28	89·75	6·67	89·72	7·06	89·69	7·45	90
91	90·78	6·35	90·75	6·74	90·72	7·14	90·69	7·54	91
92	91·78	6·42	91·75	6·82	91·72	7·22	91·68	7·62	92
93	92·77	6·49	92·74	6·89	92·71	7·30	92·68	7·70	93
94	93·77	6·56	93·74	6·97	93·71	7·38	93·68	7·78	94
95	94·77	6·63	94·74	7·04	94·71	7·45	94·67	7·87	95
96	95·77	6·70	95·74	7·11	95·70	7·53	95·67	7·95	96
97	96·76	6·77	96·73	7·19	96·70	7·61	96·67	8·03	97
98	97·76	6·84	97·73	7·26	97·70	7·69	97·66	8·12	98
99	98·76	6·91	98·73	7·34	98·69	7·77	98·66	8·20	99
100	99·76	6·98	99·73	7·41	99·69	7·85	99·66	8·28	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	86 Deg.		85¾ Deg.		85½ Deg.		85¼ Deg.		

Distance.	5 Deg.		5¼ Deg.		5½ Deg.		5¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	1·00	0·09	1·00	0·09	1·00	0·10	0·99	0·10	1
2	1·99	0·17	1·99	0·18	1·99	0·19	1·99	0·20	2
3	2·99	0·26	2·99	0·27	2·99	0·29	2·98	0·30	3
4	3·98	0·35	3·98	0·37	3·98	0·38	3·98	0·40	4
5	4·98	0·44	4·98	0·46	4·98	0·48	4·97	0·50	5
6	5·98	0·52	5·97	0·55	5·97	0·58	5·97	0·60	6
7	6·97	0·61	6·97	0·64	6·97	0·67	6·96	0·70	7
8	7·97	0·70	7·97	0·73	7·96	0·76	7·96	0·80	8
9	8·97	0·78	8·96	0·82	8·96	0·86	8·95	0·90	9
10	9·96	0·87	9·96	0·92	9·95	0·96	9·95	1·00	10
11	10·96	0·96	10·95	1·01	10·95	1·05	10·94	1·10	11
12	11·95	1·05	11·95	1·10	11·94	1·15	11·94	1·20	12
13	12·95	1·13	12·95	1·19	12·94	1·25	12·93	1·30	13
14	13·95	1·22	13·94	1·28	13·94	1·34	13·93	1·40	14
15	14·94	1·31	14·94	1·37	14·93	1·44	14·92	1·50	15
16	15·94	1·39	15·93	1·46	15·93	1·53	15·92	1·60	16
17	16·94	1·48	16·93	1·56	16·92	1·63	16·91	1·70	17
18	17·93	1·57	17·92	1·65	17·92	1·73	17·91	1·80	18
19	18·93	1·66	18·92	1·74	18·91	1·82	18·90	1·90	19
20	19.92	1·74	19·92	1·83	19·91	1·92	19·90	2·00	20
21	20·92	1·83	20·91	1·92	20·90	2·01	20·89	2·10	21
22	21·92	1·92	21·91	2·01	21·90	2·11	21·89	2·20	22
23	22·91	2·00	22·90	2·10	22·89	2·20	22·88	2·30	23
24	23·91	2·09	23·90	2·20	23·89	2·30	23·88	2·40	24
25	24·90	2·18	24·90	2·29	24·88	2·40	24·87	2·50	25
26	25·90	2·27	25·89	2·38	25·88	2·49	25·87	2·60	26
27	26·90	2·35	26·89	2·47	26·88	2·59	26·86	2·71	27
28	27·89	2·44	27·88	2·56	27·87	2·68	27·86	2·81	28
29	28·89	2·53	28·88	2·65	28·87	2·78	28·85	2·91	29
30	29·89	2·61	29·87	2·75	29·86	2·88	29·85	3·01	30
31	30·88	2·70	30·87	2·84	30·86	2·97	30·84	3·11	31
32	31·88	2·79	31·87	2·93	31·85	3·07	31·84	3·21	32
33	32·87	2·88	32·86	3·02	32·85	3·16	32·83	3·31	33
34	33·87	2·96	33·86	3·11	33·84	3·26	33·83	3·41	34
35	34·87	3·05	34·85	3·20	34·84	3·35	34·82	3·51	35
36	35·86	3·14	35·85	3·29	35·83	3·45	35·82	3·61	36
37	36·86	3·22	36·84	3·39	36·83	3·55	36·81	3·71	37
38	37·86	3·31	37·84	3·48	37·83	3·64	37·81	3·81	38
39	38·85	3·40	38·84	3·57	38·82	3·74	38·80	3·91	39
40	39·85	3·49	39·83	3·66	39·82	3·83	39·80	4·01	40
41	40·84	3·57	40·83	3·75	40·81	3·93	40·79	4·11	41
42	41·84	3·66	41·82	3·84	41·81	4·03	41·79	4·21	42
43	42·84	3·75	42·82	3·93	42·80	4·12	42·78	4·31	43
44	43·83	3·83	43·82	4·03	43·80	4·22	43·78	4·41	44
45	44·83	3·92	44·81	4·12	44·79	4·31	44·77	4·51	45
46	45·82	4·01	45·81	4·21	45·79	4·41	45·77	4·61	46
47	46·82	4·10	46·80	4·30	46·78	4·50	46·76	4·71	47
48	47·82	4·18	47·80	4·39	47·78	4·60	47·76	4·81	48
49	48·81	4·27	48·79	4·48	48·77	4·70	48·75	4·91	49
50	49·81	4·36	49·79	4·58	49·77	4·79	49·75	5·01	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	85 Deg.		84¾ Deg.		84½ Deg.		84¼ Deg.		

Distance.	5 Deg.		5¼ Deg.		5½ Deg.		5¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	50.81	4·44	50·79	4·67	50·77	4·89	50·74	5·11	51
52	51·80	4·53	51·78	4·76	51·76	4·98	51·74	5·21	52
53	52·80	4·62	52·78	4·85	52·76	5·08	52·73	5·31	53
54	53·79	4·71	53·77	4·94	53·75	5·18	53·73	5·41	54
55	54·79	4·79	54·77	5·03	54·75	5·27	54·72	5·51	55
56	55·79	4·88	55·77	5·12	55·74	5·37	55·72	5·61	56
57	56·78	4·97	56·76	5·22	56·74	5·46	56·71	5·71	57
58	57·78	5·06	57·76	5·31	57·73	5·56	57·71	5·81	58
59	58·78	5·14	58·75	5·40	58·73	5·65	58·70	5·91	59
60	59·77	5·23	59·75	5·49	59·72	5·75	59·70	6·01	60
61	60·77	5·32	60·74	5·58	60·72	5·85	60·69	6·11	61
62	61·76	5·40	61·74	5·67	61·71	5·94	61·69	6·21	62
63	62·76	5·49	62·74	5·76	62·71	6·04	62·68	6·31	63
64	63·76	5·58	63·73	5·86	63·71	6·13	63·68	6·41	64
65	64·75	5·67	64·73	5·95	64·70	6·23	64·67	6·51	65
66	65·75	5·75	65·72	6·04	65·70	6·33	65·67	6·61	66
67	66·75	5·84	66·72	6·13	66·69	6·42	66·66	6·71	67
68	67·74	5·93	67·71	6·22	67·69	6·52	67·66	6·81	68
69	68·74	6·01	68·71	6·31	68·68	6·61	68·65	6·91	69
70	69·73	6·10	69·71	6·41	69·68	6·71	69·65	7·01	70
71	70·73	6·19	70·70	6·50	70·67	6·81	70·64	7·11	71
72	71·73	6·28	71·70	6·59	71·67	6·90	71·64	7·21	72
73	72·72	6·36	72·69	6·68	72·66	7·00	72·63	7·31	73
74	73·72	6·45	73·69	6·77	73·66	7·09	73·63	7·41	74
75	74·71	6·54	74·69	6·86	74·65	7·19	74·62	7·51	75
76	75·71	6·62	75·68	6·95	75·65	7·28	75·62	7·61	76
77	76·71	6·71	76·68	7·05	76·65	7·38	76·61	7·71	77
78	77·70	6·80	77·67	7·14	77·64	7·48	77·61	7·81	78
79	78·70	6·89	78·67	7·23	78·64	7·57	78·60	7·91	79
80	79·70	6·97	79·66	7·32	79·63	7·67	79·60	8·02	80
81	80·69	7·06	80·66	7·41	80·63	7·76	80·59	8·12	81
82	81·69	7·15	81·66	7·50	81·62	7·86	81·59	8·22	82
83	82·68	7·23	82·65	7·59	82·62	7·96	82·58	8·32	83
84	83·68	7·32	83·65	7·69	83·61	8·05	83·58	8·42	84
85	84·68	7·41	84·64	7·78	84·61	8·15	84·57	8·52	85
86	85·67	7·50	85·64	7·87	85·60	8·24	85·57	8·62	86
87	86·67	7·58	86·64	7·96	86·60	8·34	85·56	8·72	87
88	87·67	7·67	87·63	8·05	87·59	8·43	87·56	8·82	88
89	88·66	7·76	88·63	8·14	88·59	8·53	88·55	8·92	89
90	89·66	7·84	89·62	8·24	89·59	8·63	89·55	9·02	90
91	90·65	7·93	90·62	8·33	90·58	8·72	90·54	9·12	91
92	91·65	8·02	91·61	8·42	91·58	8·82	91·54	9·22	92
93	92·65	8·11	92·61	8·51	92·57	8·91	92·53	9·32	93
94	93·64	8·19	93·61	8·60	93·57	9·01	93·53	9·42	94
95	94·64	8·28	94·60	8·69	94·56	9·11	94·52	9·52	95
96	95·63	8·37	95·60	8·78	95·56	9·20	95·52	9·62	96
97	96·63	8·45	96·59	8·88	96·55	9·30	96·51	9·72	97
98	97·63	8·54	97·59	8·97	97·55	9·39	97·51	9·82	98
99	98·62	8·63	98·59	9·06	98·54	9·49	98·50	9·92	99
100	99·62	8·72	99·58	9·15	99·54	9·58	99·50	10·02	100
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
Distance.	85 Deg.		84¾ Deg.		84½ Deg.		84¼ Deg.		Distance.

Distance.	6 Deg. Lat.	6 Deg. Dep.	6¼ Deg. Lat.	6¼ Deg. Dep.	6½ Deg. Lat.	6½ Deg. Dep.	6¾ Deg. Lat.	6¾ Deg. Dep.	Distance.
1	0·99	0·10	0·99	0·11	0·99	0·11	0·99	0·12	1
2	1·99	0·21	1·99	0·22	1·99	0·23	1·99	0·24	2
3	2·98	0·31	2·98	0·33	2·98	0·34	2·98	0·35	3
4	3·98	0·41	3·98	0·44	3·97	0·45	3.98	0·47	4
5	4·97	0·52	4·97	0·54	4·97	0·57	4·97	0·59	5
6	5·97	0·63	5·96	0·65	5·96	0·68	5·96	0·71	6
7	6·96	0·73	6·96	0·76	6·96	0·79	6·95	0·82	7
8	7·96	0·84	7·95	0·87	7·95	0·91	7·94	0·94	8
9	8·95	0·94	8·95	0·98	8·94	1·02	8·94	1·06	9
10	9·95	1·05	9·94	1·09	9·94	1·13	9·93	1·18	10
11	10·94	1·15	10·93	1·20	10·93	1·25	10·92	1·29	11
12	11·93	1·25	11·93	1·31	11·92	1·36	11·92	1·41	12
13	12·93	1·36	12·92	1·42	12·92	1·47	12·91	1·53	13
14	13·92	1·46	13·92	1·52	13·91	1·59	13·90	1·65	14
15	14·92	1·57	14·91	1·63	14·90	1·70	14·90	1·76	15
16	15·91	1·67	15·90	1·74	15·90	1·81	15·89	1·88	16
17	16·91	1·78	16·90	1·85	16·89	1·92	16·88	2·00	17
18	17·90	1·88	17·89	1·96	17·88	2·04	17·88	2·12	18
19	18·90	1·99	18·89	2·07	18·88	2·15	18·87	2·23	19
20	19·89	2·09	19·88	2·18	19·87	2·26	19·86	2·35	20
21	20·88	2·20	20·88	2·29	20·87	2·38	20·85	2·47	21
22	21·88	2·30	21·87	2·40	21·86	2·49	21·85	2·59	22
23	22·87	2·40	22·86	2·50	22·85	2·60	22·84	2·70	23
24	23·87	2·51	23·86	2·61	23·85	2·72	23·83	2·82	24
25	24·86	2·61	24·85	2·72	24·84	2·83	24·83	2·94	25
26	25·86	2·72	25·85	2·83	25·83	2·94	25·82	3·06	26
27	26·85	2·82	26·84	2·94	26·83	3·06	26·81	3·17	27
28	27·85	2·93	27·83	3·05	27·82	3·17	27·81	3·29	28
29	28·84	3·03	28·83	3·16	28·81	3·28	28·80	3·41	29
30	29·84	3·14	29·82	3·27	29·81	3·40	29·79	3·53	30
31	30·83	3·24	30·82	3·37	30·80	3·51	30·79	3·64	31
32	31·82	3·34	31·81	3·48	31·79	3·62	31·78	3·76	32
33	32·82	3·45	32·80	3·59	32·79	3·74	32·77	3·88	33
34	33·81	3·55	33·80	3·70	33·78	3·85	33·76	4·00	34
35	34·81	3·66	34·79	3·81	34·78	3·96	34·76	4·11	35
36	35·80	3·76	35·79	3·92	35·77	4·08	35·75	4·23	36
37	36·80	3·87	36·78	4·03	36·76	4·19	36·75	4·35	37
38	37·79	3·97	37·77	4·14	37·76	4·30	37·74	4·47	38
39	38·79	4·08	38·77	4·25	38·75	4·41	38·73	4·58	39
40	39·78	4·18	39·76	4·35	39·74	4·53	39·72	4·70	40
41	40·78	4·29	40·76	4·46	40·74	4·64	40·72	4·82	41
42	41·77	4·39	41·75	4·57	41·73	4·76	41·71	4·94	42
43	42·76	4·49	42·74	4·68	42·72	4·87	42·70	5·05	43
44	43·76	4·60	43·74	4·79	43·72	4·98	43·70	5·17	44
45	44·75	4·70	44·73	4·90	44·71	5·09	44·69	5·29	45
46	45·75	4·81	45·73	5·01	45·70	5·21	45·68	5·41	46
47	46·74	4·91	46·72	5·12	46·70	5·32	46·67	5·52	47
48	47·74	5·02	47·71	5·23	47·69	5·43	47·67	5·64	48
49	48·73	5·12	48·71	5·34	48·69	5·55	48·66	5·76	49
50	49·73	5·23	49·70	5·44	49·68	5·66	49·65	5·88	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	84 Deg.		83¾ Deg.		83½ Deg.		83¼ Deg.		

Distance.	6 Deg.		6¼ Deg.		6½ Deg.		6¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	50·72	5·33	50·70	5·55	50·67	5·77	50·65	5·99	51
52	51·72	5·44	51·69	5·66	51·67	5·89	51·64	6·11	52
53	52·71	5·54	52·68	5·77	52·66	6·00	52·63	6·23	53
54	53·70	5·64	53·68	5·88	53·65	6·11	53·63	6·25	54
55	54·70	5·75	54·67	5·99	54·65	6·23	54·62	6·46	55
56	55·69	5·85	55·67	6·10	55·64	6·34	55·61	6·58	56
57	56·69	5·96	56·66	6·21	56·63	6·45	56·60	6·70	57
58	57·68	6·06	57·66	6·31	57·63	6·57	57·60	6·82	58
59	58·68	6·17	58·65	6·42	58·62	6·68	58·59	6·93	59
60	59·67	6·27	59·64	6·53	59·61	6·79	59·58	7·05	60
61	60·67	6·38	60·64	6·64	60·61	6·91	60·58	7·17	61
62	61·66	6·48	61·63	6·75	61·60	7·02	61·57	7·29	62
63	62·65	6·59	62·63	6·86	62·60	7·13	62·56	7·40	63
64	63·65	6·69	63·62	6·97	63·59	7·25	63·56	7·52	64
65	64·64	6·79	64·61	7·08	64·58	7·36	64·55	7·64	65
66	65·64	6·90	65·61	7·19	65·58	7·47	65·54	7·76	66
67	66·63	7·00	66·60	7·29	66·57	7·58	66·54	7·88	67
68	67·63	7·11	67·60	7·40	67·56	7·70	67·53	7·99	68
69	68·62	7·21	68·59	7·51	68·56	7·81	68·52	8·11	69
70	69·62	7·32	69·58	7·62	69·55	7·92	69·51	8·23	70
71	70·61	7·42	70·58	7·73	70·54	8·04	70·51	8·35	71
72	71·61	7·53	71·57	7·84	71·54	8·15	71·50	8·46	72
73	72·60	7·63	72·57	7·95	72·53	8·26	72·49	8·58	73
74	73·59	7·74	73·56	8·06	73·52	8·38	73·49	8·70	74
75	74·59	7·84	74·55	8·17	74·52	8·49	74·48	8·82	75
76	75·58	7·94	75·55	8·27	75·51	8·60	75·47	8·93	76
77	76·58	8·05	76·54	8·38	76·51	8·72	76·47	9·05	77
78	77·57	8·15	77·54	8·49	77·50	8·83	77·46	9·17	78
79	78·57	8·26	78·53	8·60	78·49	8·94	78·45	9·29	79
80	79·56	8·36	79·53	8·71	79·49	9·06	79·45	9·40	80
81	80·56	8·47	80·52	8·82	80·48	9·17	80·44	9·52	81
82	81·55	8·57	81·51	8·93	81·47	9·28	81·43	9·64	82
83	82·55	8·68	82·51	9·04	82·47	9·40	82·42	9·76	83
84	83·54	8·78	83·50	9·14	83·46	9·51	83·42	9·87	84
85	84·53	8·88	84·50	9·25	84·45	9·62	84·41	9·99	85
86	85·53	8·99	85·49	9·36	85·45	9·74	85·40	10·11	86
87	86·52	9·09	86·48	9·47	86·44	9·85	86·40	10·23	87
88	87·52	9·20	87·48	9·58	87·43	9·96	87·39	10·34	88
89	88·51	9·30	88·47	9·69	88·43	10·08	88·38	10·46	89
90	89·51	9·41	89·47	9·80	89·42	10·19	89·38	10·58	90
91	90·50	9·51	90·46	9·91	90·42	10·30	90·37	10·70	91
92	91·50	9·62	91·45	10·02	91·41	10·41	91·36	10·81	92
93	92·49	9·72	92·45	10·12	92·40	10·53	92·36	10·93	93
94	93·49	9·83	93·44	10·23	93·40	10·64	93·35	11·05	94
95	94·48	9·93	94·44	10·34	94·39	10·75	94·34	11·17	95
96	95·47	10·03	95·43	10·45	95·38	10·87	95·33	11·28	96
97	96·47	10·14	96·42	10·56	96·38	10·98	96·33	11·40	97
98	97·46	10·24	97·42	10·67	97·37	11·09	97·32	11·52	98
99	98·46	10·35	98·41	10·78	98·36	11·21	98·31	11·64	99
100	99·45	10·45	99·41	10·89	99·36	11·32	99·31	11·75	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	84 Deg.		83¾ Deg.		83½ Deg.		83¼ Deg.		

Distance.	7 Deg.		7¼ Deg.		7½ Deg.		7¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·99	0·12	0·99	0·13	0·99	0·13	0·99	0·13	1
2	1·99	0·24	1·98	0·25	1·98	0·26	1·98	0·27	2
3	2·98	0·37	2·98	0·38	2·97	0·39	2·97	0·40	3
4	3·97	0·49	3·97	0·50	3·97	0·52	3·96	0·54	4
5	4·96	0·61	4·96	0·63	4·96	0·65	4·95	0·67	5
6	5·96	0·73	5·95	0·76	5·95	0·78	5·95	0·81	6
7	6·95	0·85	6·94	0·88	6·94	0·91	6·94	0·94	7
8	7·94	0·97	7·94	1·01	7·93	1·04	7·93	1·08	8
9	8·93	1·10	8·93	1·14	8·92	1·17	8·92	1·21	9
10	9·93	1·22	9·92	1·26	9·91	1·31	9·91	1·35	10
11	10·92	1·34	10·91	1·39	10·91	1·44	10·90	1·48	11
12	11·91	1·46	11·90	1·51	11·90	1·57	11·89	1·62	12
13	12·90	1·58	12·90	1·64	12·89	1·70	12·88	1·75	13
14	13·90	1·71	13·89	1·77	13·88	1·83	13·87	1·89	14
15	14·89	1·83	14·88	1·89	14·87	1·96	14·86	2·02	15
16	15·88	1·95	15·87	2·02	15·86	2·09	15·85	2·16	16
17	16·87	2·07	16·86	2·15	16·85	2·22	16·84	2·29	17
18	17·87	2·19	17·86	2·27	17·85	2·35	17·84	2·43	18
19	18·86	2·32	18·85	2·40	18·84	2·48	18·83	2·56	19
20	19·85	2·44	19·84	2·52	19·83	2·61	19·82	2·70	20
21	20·84	2·56	20·83	2·56	20·82	2·74	20·81	2·84	21
22	21·84	2·68	21·82	2·78	21·81	2·87	21·80	2·97	22
23	22·83	2·80	22·82	2·90	22·80	3·00	22·79	3·10	23
24	23·82	2·92	23·81	3·03	23·79	3·13	23·78	3·24	24
25	24·81	3·05	24·80	3·15	24·79	3·26	24·77	3·37	25
26	25·81	3·17	25·79	3·28	25·78	3·39	25·76	3·51	26
27	26·80	3·29	26·78	3·41	26·77	3·52	26·75	3·64	27
28	27·79	3·41	27·78	3·53	27·76	3·65	27·74	3·78	28
29	28·78	3·53	28·77	3·66	28·75	3·79	28·74	3·91	29
30	29·78	3·66	29·76	3·79	29·74	3·92	29·73	4·05	30
31	30·77	3·78	30·75	3·91	30·73	4·05	30·72	4·18	31
32	31·76	3·90	31·74	4·04	31·73	4·18	31·71	4·32	32
33	32·75	4·02	32·74	4·16	32·72	4·31	32·70	4·45	33
34	33·75	4·14	33·73	4·29	33·81	4·44	33·69	4·58	34
35	34·74	4·27	34·72	4·42	34·70	4·57	34·68	4·72	35
36	35·73	4·39	35·71	4·54	35·69	4·70	35·67	4·85	36
37	36·72	4·51	36·70	4·67	36·68	4·83	36·66	4·99	37
38	37·72	4·63	37·70	4·80	37·67	4·96	37·65	5·12	38
39	38·71	4·75	38·69	4·92	38·67	5·09	38·64	5·26	39
40	39·70	4·87	39·68	5·05	39·66	5·22	39·63	5·39	40
41	40·70	5·00	40·67	5·17	40·65	5·35	40·63	5·53	41
42	41·69	5·12	41·66	5·30	41·64	5·48	41·62	5·66	42
43	42·68	5·24	42·66	5·43	42·63	5·61	42·61	5·80	43
44	43·67	5·36	43·65	5·55	43·62	5·74	43·60	5·93	44
45	44·67	5·48	44·64	5·68	44·62	5·87	44·59	6·07	45
46	45·66	5·61	45·63	5·81	45·61	6·00	45·58	6·20	[illegible]
47	46·65	5·73	46·62	5·93	46·60	6·13	46·57	6·34	[illegible]
48	47·64	5·85	47·62	6·06	47·59	6·27	47·56	6·47	[illegible]
49	48·63	5·97	48·61	6·18	48·58	6·40	48·55	6·61	[illegible]
50	49·63	6·09	49·60	6·31	49·57	6·53	49·54	[illegible]	[illegible]
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	[illegible]	[illegible]	
Distance.	83 Deg.		82¾ Deg.		82½ Deg.		[illegible]		[illegible]

Distance.	7 Deg.		7¼ Deg.		7½ Deg.		7¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	50·62	6·22	50·59	6·44	50·56	6·66	50·53	6·88	51
52	51·61	6·34	51·58	6·56	51·56	6·79	51·53	7·01	52
53	52·60	6·46	52·58	6·69	52·55	6·92	52·52	7·15	53
54	53·60	6·58	53·57	6·81	53·54	7·05	53·51	7·28	54
55	54·59	6·70	54·56	6·94	54·53	7·18	54·50	7·42	55
56	55·58	6·82	55·55	7·07	55·52	7·31	55·49	7·55	56
57	56·58	6·95	56·54	7·19	56·51	7·44	56·48	7·69	57
58	57·57	7·07	57·54	7·32	57·50	7·57	57·47	7·82	58
59	58·56	7·19	58·53	7·45	58·50	7·70	58·46	7·96	59
60	59·55	7·31	59·52	7·57	59·49	7·83	59·45	8·09	60
61	60·55	7·43	60·51	7·70	60·48	7·96	60·44	8·23	61
62	61·54	7·56	61·50	7·82	61·47	8·09	61·43	8·36	62
63	62·53	7·68	62·50	7·95	62·46	8·22	62·42	8·50	63
64	63·52	7·80	63·49	8·08	63·45	8·35	63·42	8·63	64
65	64·52	7·92	64·48	8·20	64·44	8·48	64·41	8·77	65
66	65·51	8·04	65·47	8·33	65·44	8·61	65·40	8·90	66
67	66·50	8·17	66·46	8·46	66·43	8·75	66·39	9·04	67
68	67·49	8·29	67·46	8·58	67·42	8·88	67·38	9·17	68
69	68·49	8·41	68·45	8·71	68·41	9·01	68·37	9·30	69
70	69·48	8·53	69·44	8·83	69·40	9·14	69·36	9·44	70
71	70·47	8·65	70·43	8·96	70·39	9·27	70·35	9·57	71
72	71·46	8·77	71·42	9·09	71·38	9·40	71·34	9·71	72
73	72·46	8·90	72·42	9·21	72·38	9·53	72·33	9·84	73
74	73·45	9·02	73·41	9·34	73·37	9·66	73·32	9·98	74
75	74·44	9·14	74·40	9·46	74·36	9·79	74·31	10·11	75
76	75·43	9·26	75·39	9·59	75·35	9·92	75·31	10·25	76
77	76·43	9·38	76·38	9·72	76·34	10·05	76·30	10·38	77
78	77·42	9·51	77·38	9·84	77·33	10·18	77·29	10·52	78
79	78·41	9·63	78·37	9·97	78·32	10·31	78·28	10·65	79
80	79·40	9·75	79·36	10·10	79·32	10·44	79·27	10·79	80
81	80·40	9·87	80·35	10·22	80·31	10·57	80·26	10·92	81
82	81·39	9·99	81·34	10·35	81·30	10·70	81·25	11·06	82
83	82·38	10·12	82·34	10·47	82·29	10·83	82·24	11·19	83
84	83·37	10·24	83·33	10·60	83·28	10·96	83·23	11·33	84
85	84·37	10·36	84·32	10·73	84·27	11·09	84·22	11·46	85
86	85·36	10·48	85·31	10·85	85·26	11·23	85·21	11·60	86
87	86·35	10·60	86·30	10·98	86·26	11·36	86·21	11·73	87
88	87·34	10·72	87·30	11·11	87·25	11·49	87·20	11·87	88
89	88·34	10·85	88·29	11·23	88·24	11·62	88·19	12·00	89
90	89·33	10·97	89·28	11·36	89·23	11·75	89·18	12·14	90
91	90·32	11·09	90·27	11·48	90·22	11·88	90·17	12·27	91
92	91·31	11·21	91·26	11·61	91·21	12·01	91·16	12·41	92
93	92·31	11·33	92·26	11·74	92·20	12·14	92·15	12·54	93
94	93·30	11·46	93·25	11·86	93·20	12·27	93·14	12·68	94
95	94·29	11·58	94·24	11·99	94·19	12·40	94·13	12·81	95
96	95·28	11·70	95·23	12·12	95·18	12·53	95·12	12·95	96
97	96·28	11·82	96·22	12·24	96·17	12·66	96·11	13·08	97
98	97·27	11·94	97·22	12·37	97·16	12·79	97·10	13·22	98
99	98·26	12·07	98·21	12·49	98·15	12·92	98·10	13·35	99
100	99·25	12·19	99·20	12·62	99·14	13·05	99·09	13·49	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	83 Deg.		82¾ Deg.		82½ Deg.		82¼ Deg.		

Distance.	8 Deg.		8¼ Deg.		8½ Deg.		8¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·99	0·14	0·99	0·14	0·99	0·15	0·99	0·15	1
2	1·98	0·28	1·98	0·29	1·98	0·30	1·98	0·30	2
3	2·97	0·42	2·97	0·43	2·97	0·44	2·97	0·46	3
4	3·96	0·56	3·96	0·57	3·96	0·59	3·95	0·61	4
5	4·95	0·70	4·95	0·72	4·95	0·74	4·94	0·76	5
6	5·94	0·84	5·94	0·86	5·93	0·98	5·93	0·91	6
7	6·93	0·97	6·93	1·00	6·92	1·03	6·92	1·06	7
8	7·92	1·11	7·92	1·15	7·91	1·18	7·91	1·22	8
9	8·91	1·25	8·91	1·29	8·90	1·33	8·90	1·37	9
10	9·90	1·39	9·90	1·43	9·89	1·48	9·88	1·52	10
11	10·89	1·53	10·89	1·58	10·88	1·63	10·87	1·67	11
12	11·88	1·67	11·88	1·72	11·87	1·77	11·86	1·83	12
13	12·87	1·81	12·87	1·87	12·86	1·92	12·85	1·98	13
14	13·86	1·95	13·86	2·01	13·85	2·07	13·84	2·13	14
15	14·85	2·09	14·85	2·15	14·84	2·22	14·83	2·28	15
16	15·84	2·23	15·84	2·30	15·82	2·36	15·81	2·43	16
17	16·83	2·37	16·83	2·44	16·81	2·51	16·80	2·59	17
18	17·82	2·51	17·81	2·58	17·80	2·66	17·79	2·74	18
19	18·82	2·64	18·80	2·73	18·79	2·81	18·78	2·89	19
20	19·81	2·78	19·79	2·87	19·78	2·96	19·77	3·04	20
21	20·80	2·92	20·78	3·01	20·77	3·10	20·76	3·19	21
22	21·79	3·06	21·77	3·16	21·76	3·25	21·74	3·35	22
23	22·78	3·20	22·76	3·30	22·75	3·40	22·73	3·50	23
24	23·77	3·34	23·75	3·44	23·74	3·55	23·72	3·65	24
25	24·76	3·48	24·74	3·59	24·73	3·70	24·71	3·80	25
26	25·75	3·62	25·73	3·73	25·71	3·84	25·70	3·96	26
27	26·74	3·76	26·72	3·87	26·70	3·99	26·69	4·11	27
28	27·73	3·90	27·71	4·02	27·69	4·14	27·67	4·26	28
29	28·72	4·04	28·70	4·16	28·68	4·29	28·66	4·41	29
30	29·71	4·18	29·69	4·30	29·67	4·43	29·65	4·56	30
31	30·70	4·31	30·68	4·45	30·66	4·58	30·64	4·72	31
32	31·69	4·45	31·67	4·59	31·65	4·73	31·63	4·87	32
33	32·68	4·59	32·66	4·74	32·64	4·88	32·62	5·02	33
34	33·67	4·73	33·65	4·88	33·63	5·03	33·60	5·17	34
35	34·66	4·87	34·64	5·02	34·62	5·17	34·59	5·32	35
36	35·65	5·01	35·63	5·17	35·60	5·32	35·58	5·48	36
37	36·64	5·15	36·62	5·31	36·59	5·47	36·57	5·63	37
38	37·63	5·29	37·61	5·45	37·58	5·62	37·56	5·78	38
39	38·62	5·43	38·60	5·60	38·57	5·76	38·55	5·93	39
40	39·61	5·57	39·59	5·74	39·56	5·91	39·53	6·08	40
41	40·60	5·71	40·58	5·88	40·55	6·06	40·52	6·24	41
42	41·59	5·85	41·57	6·03	41·54	6·21	41·51	6·39	42
43	42·58	5·98	42·56	6·17	42·53	6·36	42·50	6·54	43
44	43·57	6·12	43·54	6·31	43·52	6·50	43·49	6·69	44
45	44·56	6·26	44·53	6·46	44·51	6·65	44·48	6·85	45
46	45·55	6·40	45·52	6·60	45·49	6·80	45·46	7·00	46
47	46·54	6·54	46·51	6·74	46·48	6·95	46·45	7·15	47
48	47·53	6·68	47·50	6·89	47·47	7·09	47·44	7·30	48
49	48·52	6·82	48·49	7·03	48·46	7·24	48·43	7·45	49
50	49·51	6·96	49·48	7·17	49·45	7·39	49·42	7·61	50
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
Distance.	82 Deg.		81¾ Deg.		81½ Deg.		81¼ Deg.		Distance.

Distance.	8 Deg. Lat.	8 Deg. Dep.	8¼ Deg. Lat.	8¼ Deg. Dep.	8½ Deg. Lat.	8½ Deg. Dep.	8¾ Deg. Lat.	8¾ Deg. Dep.	Distance.
51	50·50	7·10	50·47	7·32	50·44	7·54	50·41	7·76	51
52	51·49	7·24	51·46	7·46	51·43	7·69	51·39	7·91	52
53	52·48	7·38	52·45	7·61	52·42	7·83	52·38	8·06	53
54	53·47	7·52	53·44	7·75	53·41	7·98	53·37	8·21	54
55	54·46	7·65	54·43	7·89	54·40	8·13	54·36	8·37	55
56	55·46	7·79	55·42	8·04	55·38	8·28	55·35	8·52	56
57	56·45	7·93	56·41	8·18	56·37	8·43	56·34	8·67	57
58	57·44	8·07	57·40	8·32	57·36	8·57	57·32	8·82	58
59	58·43	8·21	58·39	8·47	58·35	8·72	58·31	8·98	59
60	59·42	8·35	59·38	8·61	59·34	8·87	59·30	9·13	60
61	60·41	8·49	60·37	8·75	60·33	9·02	60·29	9·28	61
62	61·40	8·63	61·36	8·90	61·32	9·16	61·28	9·43	62
63	62·39	8·77	62·35	9·04	62·31	9·31	62·27	9·58	63
64	63·38	8·91	63·34	9·18	63·30	9·46	63·26	9·74	64
65	64·37	9·05	64·33	9·33	64·29	9·61	64·24	9·89	65
66	65·36	9·19	65·32	9·47	65·28	9·76	65·23	10·04	66
67	66·35	9·32	66·31	9·61	66·26	9·90	66·22	10·19	67
68	67·34	9·46	67·30	9·76	67·25	10·05	67·21	10·34	68
69	68·33	9·60	68·29	9·90	68·24	10·20	68·20	10·50	69
70	69·32	9·74	69·28	10·04	69·23	10·35	69·19	10·65	70
71	70·31	9·88	70·27	10·19	70·22	10·49	70·17	10·80	71
72	71·30	10·02	71·25	10·33	71·21	10·64	71·16	10·95	72
73	72·29	10·16	72·24	10·47	72·20	10·79	72·15	11·10	73
74	73·28	10·30	73·23	10·62	73·19	10·94	73·14	11·26	74
75	74·27	10·44	74·22	10·76	74·18	11·09	74·13	11·41	75
76	75·26	10·58	75·21	10·91	75·17	11·23	75·12	11·56	76
77	76·25	10·72	76·20	11·05	76·15	11·38	76·10	11·71	77
78	77·24	10·86	77·19	11·19	77·14	11·53	77·09	11·87	78
79	78·23	10·99	78·18	11·34	78·13	11·68	78·08	12·02	79
80	79·22	11·13	79·17	11·48	79·12	11·82	79·07	12·17	80
81	80·21	11·27	80·16	11·62	80·11	11·97	80·06	12·32	81
82	81·20	11·41	81·15	11·77	81·10	12·12	81·05	12·47	82
83	82·19	11·55	82·14	11·91	82·09	12·27	82·03	12·63	83
84	83·18	11·69	83·13	12·05	83·08	12·42	83·02	12·78	84
85	84·17	11·83	84·12	12·20	84·07	12·56	84·01	12·93	85
86	85·16	11·97	85·11	12·34	85·06	12·71	85·00	13·08	86
87	86·15	12·11	86·10	12·48	86·04	12·86	85·99	13·23	87
88	87·14	12·25	87·09	12·63	87·03	13·01	86·98	13·39	88
89	88·13	12·39	88·08	12·77	88·02	13·16	87·96	13·54	89
90	89·12	12·53	89·07	12·91	89·01	13·30	88·95	13·69	90
91	90·11	12·66	90·06	13·06	90·00	13·45	89·94	13·84	91
92	91·10	12·80	91·05	13·20	90·99	13·60	90·93	14·00	92
93	92·09	12·94	92·04	13·34	91·98	13·75	91·92	14·15	93
94	93·09	13·08	93·03	13·49	92·97	13·89	92·91	14·30	94
95	94·08	13·22	94·02	13·63	93·96	14·04	93·89	14·45	95
96	95·07	13·36	95·01	13·78	94·95	14·19	94·88	14·60	96
97	96·06	13·50	96·00	13·92	95·93	14·34	95·87	14·76	97
98	97·05	13·64	96·99	14·06	96·92	14·49	96·86	14·91	98
99	98·04	13·78	97·98	14·21	97·91	14·63	97·85	15·06	99
100	99·03	13·92	98·97	14·35	98·90	14·78	98·84	15·21	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	82 Deg.		81¾ Deg.		81½ Deg.		81¼ Deg.		

Distance.	9 Deg.		9¼ Deg.		9½ Deg.		9¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·99	0·16	0·99	0·16	0·99	0·17	0·99	0·17	1
2	1·98	0·31	1·97	0·32	1·97	0·33	1·97	0·34	2
3	2·96	0·47	2·96	0·48	2·96	0·50	2·96	0·51	3
4	3·95	0·63	3·95	0·64	3·95	0·66	3·94	0·68	4
5	4·94	0·78	4·93	0·80	4·93	0·83	4·93	0·85	5
6	5·93	0·94	5·92	0·96	5·92	0·99	5·91	1·02	6
7	6·91	1·10	6·91	1·13	6·90	1·16	6·90	1·19	7
8	7·90	1·25	7·90	1·29	7·89	1·32	7·88	1·35	8
9	8·89	1·41	8·88	1·45	8·88	1·49	8·87	1·52	9
10	9·88	1·56	9·87	1·61	9·86	1·65	9·86	1·69	10
11	10·86	1·72	10·86	1·77	10·85	1·82	10·84	1·86	11
12	11·85	1·88	11·84	1·93	11·84	1·98	11·83	2·03	12
13	12·84	2·03	12·83	2·09	12·82	2·15	12·81	2·20	13
14	13·83	2·19	13·82	2·25	13·81	2·31	13·80	2·37	14
15	14·82	2·35	14·80	2·41	14·79	2·48	14·78	2·54	15
16	15·80	2·50	15·79	2·57	15·78	2·64	15·77	2·71	16
17	16·79	2·66	16·78	2·73	16·77	2·81	16·75	2·88	17
18	17·78	2·82	17·77	2·89	17·75	2·97	17·74	3·05	18
19	18·77	2·97	18·75	3·05	18·74	3·14	18·73	3·22	19
20	19·75	3·13	19·74	3·21	19·73	3·30	19·71	3·39	20
21	20·74	3·29	20·73	3·38	20·71	3·47	20·70	3·56	21
22	21·73	3·44	21·71	3·54	21·70	3·63	21·68	3·73	22
23	22·72	3·60	22·70	3·70	22·68	3·80	22·67	3·90	23
24	23·70	3·75	23·69	3·86	23·67	3·96	23·65	4·06	24
25	24·69	3·91	24·67	4·02	24·66	4·13	24·64	4·23	25
26	25·68	4·07	25·66	4·18	25·64	4·29	25·62	4·40	26
27	26·67	4·22	26·65	4·34	26·63	4·46	26·61	4·57	27
28	27·66	4·38	27·64	4·50	27·62	4·62	27·60	4·74	28
29	28·64	4·54	28·62	4·66	28·60	4·79	28·58	4·91	29
30	29·63	4·69	29·61	4·82	29·59	4·95	29·57	5·08	30
31	30·62	4·85	30·60	4·98	30·57	5·12	30·55	5·25	31
32	31·61	5·01	31·58	5·14	31·56	5·28	31·54	5·42	32
33	32·59	5·16	32·57	5·30	32·55	5·45	32·52	5·59	33
34	33·58	5·32	33·56	5·47	33·53	5·61	33·51	5·76	34
35	34·57	5·48	34·54	5·63	34·52	5·78	34·49	5·93	35
36	35·56	5·63	35·53	5·79	35·51	5·94	35·48	6·10	36
37	36·54	5·79	36·52	5·95	36·49	6·11	36·47	6·27	37
38	37·53	5·94	37·51	6·11	37·48	6·27	37·45	6·44	38
39	38·52	6·10	38·49	6·27	38·47	6·44	38·44	6·60	39
40	39·51	6·26	39·48	6·43	39·45	6·60	39·42	6·77	40
41	40·50	6·41	40·47	6·59	40·44	6·77	40·41	6·94	41
42	41·48	6·57	41·45	6·75	41·42	6·92	41·39	7·11	42
43	42·47	6·73	42·44	6·91	42·41	7·10	42·38	7·28	43
44	43·46	6·88	43·43	7·07	43·40	7·26	43·36	7·45	44
45	44·45	7·04	44·41	7·23	44·38	7·43	44·35	7·62	45
46	45·43	7·20	45·40	7·39	45·37	7·59	45·34	7·79	46
47	46·42	7·35	46·39	7·55	46·36	7·76	46·32	7·96	47
48	47·41	7·51	47·38	7·72	47·34	7·92	47·31	8·13	48
49	48·40	7·67	48·36	7·88	48·33	8·09	48·29	8·30	49
50	49·38	7·82	49·35	8·04	49·32	8·25	49·28	8·47	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	81 Deg.		80¾ Deg.		80½ Deg.		80¼ Deg.		

Distance.	9 Deg.		9¼ Deg.		9½ Deg.		9¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	50·37	7·98	50·34	8·20	50·30	8·42	50·26	8·64	51
52	51·36	8·13	51·32	8·36	51·29	8·58	51·25	8·81	52
53	52·35	8·29	52·31	8·52	52·27	8·75	52·23	8·98	53
54	53·34	8·45	53·30	8·68	53·26	8·91	53·22	9·14	54
55	54·32	8·60	54·28	8·84	54·25	9·08	54·21	9·31	55
56	55·31	8·76	55·27	9·00	55·23	9·24	55·19	9·48	56
57	56·30	8·92	56·26	9·16	56·22	9·41	56·18	9·65	57
58	57·29	9·07	57·25	9·32	57·20	9·57	57·16	9·82	58
59	58·27	9·23	58·23	9·48	58·19	9·74	58·15	9·99	59
60	59·26	9·39	59·22	9·64	59·18	9·90	59·13	10·16	60
61	60·25	9·54	60·21	9·81	60·16	10·07	60·12	10·33	61
62	61·24	9·70	61·19	9·97	61·15	10·23	61·10	10·50	62
63	62·22	9·86	62·18	10·13	62·14	10·40	62·09	10·67	63
64	63·21	10·01	63·17	10·29	63·12	10·56	63·08	10·84	64
65	64·20	10·17	64·15	10·45	64·11	10·73	64·06	11·01	65
66	65·19	10·32	65·14	10·61	65·09	10·89	65·05	11·18	66
67	66·18	10·48	66·13	10·77	66·08	11·06	66·03	11·35	67
68	67·16	10·64	67·12	10·93	67·07	11·22	67·02	11·52	68
69	68·15	10·79	68·10	11·09	68·05	11·39	68·00	11·69	69
70	69·14	10·95	69·09	11·25	69·04	11·55	68·99	11·85	70
71	70·13	11·11	70·08	11·41	70·03	11·72	69·97	12·02	71
72	71·11	11·26	71·06	11·57	71·01	11·88	70·96	12·19	72
73	72·10	11·42	72·05	11·73	72·00	12·05	71·95	12·36	73
74	73·09	11·58	73·04	11·89	72·99	12·21	72·93	12·53	74
75	74·08	11·73	74·02	12·06	73·97	12·38	73·92	12·70	75
76	75·06	11·89	75·01	12·22	74·96	12·54	74·90	12·87	76
77	76·05	12·05	76·00	12·38	75·94	12·71	75·89	13·04	77
78	77·04	12·20	76·99	12·54	76·93	12·87	76·87	13·21	78
79	78·03	12·36	77·97	12·70	77·92	13·04	77·86	13·38	79
80	79·02	12·51	78·96	12·86	78·90	13·20	78·84	13·55	80
81	80·00	12·67	79·95	13·02	79·89	13·37	79·83	13·72	81
82	80·99	12·83	80·93	13·18	80·88	13·53	80·82	13·89	82
83	81·98	12·98	81·92	13·34	81·86	13·70	81·80	14·06	83
84	82·97	13·14	82·91	13·50	82·85	13·86	82·79	14·23	84
85	83·95	13·30	83·89	13·66	83·83	14·03	83·77	14·39	85
86	84·94	13·45	84·88	13·82	84·82	14·19	84·76	14·56	86
87	85·93	13·61	85·87	13·98	85·81	14·36	85·74	14·73	87
88	86·92	13·77	86·86	14·15	86·79	14·52	86·73	14·90	88
89	87·90	13·92	87·84	14·31	87·78	14·69	87·71	15·07	89
90	88·89	14·08	88·83	14·47	88·77	14·85	88·70	15·24	90
91	89·88	14·24	89·82	14·63	89·75	15·02	89·69	15·41	91
92	90·87	14·39	90·80	14·79	90·74	15·18	90·67	15·58	92
93	91·86	14·55	91·79	14·95	91·72	15·35	91·66	15·75	93
94	92·84	14·70	92·78	15·11	92·71	15·51	92·64	15·92	94
95	93·83	14·86	93·76	15·27	93·70	15·68	93·63	16·09	95
96	94·82	15·02	94·75	15·43	94·68	15·84	94·61	16·26	96
97	95·81	15·17	95·74	15·59	95·67	16·01	95·60	16·43	97
98	96·79	15·33	96·73	15·75	96·66	16·17	96·58	16·60	98
99	97·78	15·49	97·71	15·91	97·64	16·34	97·57	16·77	99
100	98·77	15·64	98·70	16·07	98·63	16·50	98·56	16·93	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	81 Deg.		80¾ Deg.		80½ Deg.		80¼ Deg.		

Distance.	10 Deg.		10¼ Deg.		10½ Deg.		10¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·98	0·17	0·98	0·18	0·98	0·18	0·98	0·19	1
2	1·97	0·35	1·97	0·36	1·97	0·36	1·96	0·37	2
3	2·95	0·52	2·95	0·53	2·95	0·55	2·95	0·56	3
4	3·94	0·69	3·94	0·71	3·93	0·73	3·93	0·75	4
5	4·92	0·87	4·92	0·89	4·92	0·91	4·91	0·93	5
6	5·91	1·04	5·90	1·07	5·90	1·09	5·89	1·12	6
7	6·89	1·22	6·89	1·25	6·88	1·28	6·88	1·31	7
8	7·88	1·39	7·87	1·42	7·87	1·46	7·86	1·49	8
9	8·86	1·56	8·86	1·60	8·85	1·64	8·84	1·68	9
10	9·85	1·74	9·84	1·78	9·83	1·82	9·82	1·87	10
11	10·83	1·91	10·82	1·96	10·82	2·00	10·81	2·05	11
12	11·82	2·08	11·81	2·14	11·80	2·19	11·79	2·24	12
13	12·80	2·26	12·79	2·31	12·78	2·37	12·77	2·42	13
14	13·79	2·43	13·78	2·49	13·77	2·55	13·75	2·61	14
15	14·77	2·60	14·76	2·67	14·75	2·73	14·74	2·80	15
16	15·76	2·78	15·74	2·85	15·73	2·92	15·72	2·98	16
17	16·74	2·95	16·73	3·03	16·72	3·10	16·70	3·17	17
18	17·73	3·13	17·71	3·20	17·70	3·28	17·68	3·36	18
19	18·71	3·30	18·70	3·38	18·68	3·46	18·67	3·54	19
20	19·70	3·47	19·68	3·56	19·67	3·64	19·65	3·73	20
21	20·68	3·65	20·66	3·74	20·65	3·83	20·63	3·92	21
22	21·67	3·82	21·65	3·91	21·63	4·01	21·61	4·10	22
23	22·65	3·99	22·63	4·09	22·61	4·19	22·60	4·29	23
24	23·64	4·17	23·62	4·27	23·60	4·37	23·58	4·48	24
25	24·62	4·34	24·60	4·45	24·58	4·56	24·56	4·66	25
26	25·61	4·51	25·59	4·63	25·56	4·74	25·54	4·85	26
27	26·59	4·69	26·57	4·80	26·55	4·92	26·53	5·04	27
28	27·57	4·86	27·55	4·98	27·53	5·10	27·51	5·22	28
29	28·56	5·04	28·54	5·16	28·51	5·28	28·49	5·41	29
30	29·54	5·21	29·52	5·34	29·50	5·47	29·47	5·60	30
31	30·53	5·38	30·51	5·52	30·48	5·65	30·46	5·78	31
32	31·51	5·56	31·49	5·69	31·46	5·83	31·44	5·97	32
33	32·50	5·73	32·47	5·87	32·45	6·01	32·42	6·16	33
34	33·48	5·90	33·46	6·05	33·43	6·20	33·40	6·34	34
35	34·47	6·08	34·44	6·23	34·41	6·38	34·39	6·53	35
36	35·45	6·25	35·43	6·41	35·40	6·56	35·37	6·71	36
37	36·44	6·42	36·41	6·58	36·38	6·74	36·35	6·90	37
38	37·42	6·60	37·39	6·76	37·36	6·92	37·33	7·09	38
39	38·41	6·77	38·38	6·94	38·35	7·11	38·32	7·27	39
40	39·39	6·95	39·36	7·12	39·33	7·29	39·30	7·46	40
41	40·38	7·12	40·35	7·30	40·31	7·47	40·28	7·65	41
42	41·36	7·29	41·33	7·47	41·30	7·65	41·26	7·83	42
43	42·35	7·47	42·31	7·65	42·28	7·84	42·25	8·02	43
44	43·33	7·64	43·30	7·83	43·26	8·02	43·23	8·21	44
45	44·32	7·81	44·28	8·01	44·25	8·20	44·21	8·39	45
46	45·30	7·99	45·27	8·19	45·23	8·38	45·19	8·58	46
47	46·29	8·16	46·25	8·36	46·21	8·57	46·18	8·77	47
48	47·27	8·34	47·23	8·54	47·20	8·75	47·16	8·95	48
49	48·26	8·51	48·22	8·72	48·18	8·93	48·14	9·14	49
50	49·24	8·68	49·20	8·90	49·16	9·11	49·12	9·33	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	80 Deg.		79¾ Deg.		79½ Deg.		79¼ Deg.		

Distance.	10 Deg.		10¼ Deg.		10½ Deg.		10¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	50·23	8·86	50·19	9·08	50·15	9·29	50·10	9·51	51
52	51·21	9·03	51·17	9·25	51·13	9·48	51·09	9·70	52
53	52·19	9·20	52·15	9·43	52·11	9·66	52·07	9·89	53
54	53·18	9·38	53·14	9·61	53·10	9·84	53·05	10·07	55
55	54·16	9·55	54·12	9·79	54·08	10·02	54·03	10·26	54
56	55·15	9·72	55·11	9·96	55·06	10·21	55·02	10·45	56
57	56·13	9·90	56·09	10·14	56·05	10·39	56·00	10·63	57
58	57·12	10·07	57·07	10·32	57·03	10·57	56·98	10·82	58
59	58·10	10·25	58·06	10·50	58·01	10·75	57·96	11·00	59
60	59·09	10·42	59·04	10·68	59·00	10·93	58·95	11·19	60
61	60·07	10·59	60·03	10·85	59·98	11·12	59·93	11·38	61
62	61·06	10·77	61·01	11·03	60·96	11·30	60·91	11·56	62
63	62·04	10·94	61·99	11·21	61·95	11·48	61·89	11·75	63
64	63·03	11·11	62·98	11·39	62·93	11·66	62·88	11·94	64
65	64·01	11·29	63·96	11·57	63·91	11·85	63·86	12·12	65
66	65·00	11·46	64·95	11·74	64·89	12·03	64·84	12·31	66
67	65·98	11·63	65·93	11·92	65·88	12·21	65·82	12·50	67
68	66·97	11·81	66·91	12·10	66·86	12·39	66·81	12·68	68
69	67·95	11·98	67·90	12·28	67·84	12·57	67·79	12·87	69
70	68·94	12·16	68·88	12·46	68·83	12·76	68·77	13·06	70
71	69·92	12·33	69·87	12·63	69·81	12·94	69·75	13·24	71
72	70·91	12·50	70·85	12·81	70·79	13·12	70·74	13·43	72
73	71·89	12·68	71·83	12·99	71·78	13·30	71·72	13·62	73
74	72·88	12·85	72·82	13·17	72·76	13·49	72·70	13·80	74
75	73·86	13·02	73·80	13·35	73·74	13·67	73·68	13·99	75
76	74·85	13·20	74·79	13·52	74·73	13·85	74·67	14·18	76
77	75·83	13·37	75·77	13·70	75·71	14·03	75·65	14·36	77
78	76·82	13·54	76·76	13·88	76·69	14·21	76·63	14·55	78
79	77·80	13·72	77·74	14·06	77·68	14·40	77·61	14·74	79
80	78·78	13·89	78·72	14·24	78·66	14·58	78·60	14·92	80
81	79·77	14·07	79·71	14·41	79·64	14·76	79·58	15·11	81
82	80·75	14·24	80·69	14·59	80·63	14·94	80·56	15·29	82
83	81·74	14·41	81·68	14·77	81·61	15·13	81·54	15·48	83
84	82·72	14·59	82·66	14·95	82·59	15·31	82·53	15·67	84
85	83·71	14·76	83·64	15·13	83·58	15·49	83·51	15·85	85
86	84·69	14·93	84·63	15·30	84·56	15·67	84·49	16·04	86
87	85·68	15·11	85·61	15·48	85·54	15·85	85·47	16·23	87
88	86·66	15·28	86·60	15·66	86·53	16·04	86·46	16·41	88
89	87·65	15·45	87·58	15·84	87·51	16·22	87·44	16·60	89
90	88·63	15·63	88·56	16·01	88·49	16·40	88·42	16·79	90
91	89·62	15·80	89·55	16·19	89·48	16·58	89·40	16·97	91
92	90·60	15·98	90·53	16·37	90·46	16·77	90·39	17·16	92
93	91·59	16·15	91·52	16·55	91·44	16·95	91·37	17·35	93
94	92·57	16·32	92·50	16·73	92·43	17·13	92·35	17·53	94
95	93·56	16·50	93·48	16·90	93·41	17·31	93·33	17·72	95
96	94·54	16·67	94·47	17·08	94·39	17·49	94·32	17·91	96
97	95·53	16·84	95·45	17·26	95·38	17·68	95·30	18·09	97
98	96·51	17·02	96·44	17·44	96·36	17·86	96·28	18·28	98
99	97·50	17·19	97·42	17·62	97·34	18·04	97·26	18·47	99
100	98·48	17·36	98·40	17·79	98·33	18·22	98·25	18·65	100
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
Distance.	80 Deg.		79¾ Deg.		79½ Deg.		79¼ Deg.		Distance.

Distance.	11 Deg.		11¼ Deg.		11½ Deg.		11¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·98	0·19	0·98	0·20	0·98	0·20	0·98	0·20	1
2	1·96	0·38	1·96	0·39	1·96	0·40	1·96	0·41	2
3	2·94	0·57	2·94	0·59	2·94	0·60	2·94	0·61	3
4	3·93	0·76	3·92	0·78	3·92	0·80	3·92	0·82	4
5	4·91	0·95	4·90	0·98	4·90	1·00	4·90	1·02	5
6	5·89	1·14	5·88	1·17	5·88	1·20	5·87	1·22	6
7	6·87	1·34	6·87	1·37	6·86	1·40	6·85	1·43	7
8	7·85	1·53	7·85	1·56	7·84	1·59	7·83	1·63	8
9	8·83	1·72	8·83	1·76	8·82	1·79	8·81	1·83	9
10	9·82	1·91	9·81	1·95	9·80	1·99	9·79	2·04	10
11	10·80	2·10	10·79	2·15	10·78	2·19	10·77	2·24	11
12	11·78	2·29	11·77	2·34	11·76	2·39	11·75	2·44	12
13	12·76	2·48	12·75	2·54	12·74	2·59	12·73	2·65	13
14	13·74	2·67	13·73	2·73	13·72	2·79	13·71	2·85	14
15	14·72	2·86	14·71	2·93	14·70	2·99	14·69	3·06	15
16	15·71	3·05	15·69	3·12	15·68	3·19	15·66	3·26	16
17	16·69	3·24	16·67	3·32	16·66	3·39	16·64	3·46	17
18	17·67	3·43	17·65	3·51	17·64	3·59	17·62	3·66	18
19	18·65	3·63	18·63	3·71	18·62	3·79	18·60	3·87	19
20	19·63	3·82	19·62	3·90	19·60	3·99	19·58	4·07	20
21	20·61	4·01	20·60	4·10	20·58	4·19	20·56	4·28	21
22	21·60	4·20	21·58	4·29	21·56	4·39	21·54	4·48	22
23	22·58	4·39	22·56	4·49	22·54	4·59	22·52	4·68	23
24	23·56	4·58	23·54	4·68	23·52	4·78	23·50	4·89	24
25	24·54	4·77	24·52	4·88	24·50	4·98	24·48	5·09	25
26	25·52	4·96	25·50	5·07	25·48	5·18	25·46	5·30	26
27	26·50	5·15	26·48	5·27	26·46	5·38	26·43	5·50	27
28	27·49	5·34	27·46	5·46	27·44	5·58	27·41	5·70	28
29	28·47	5·53	28·44	5·66	28·42	5·78	28·39	5·91	29
30	29·45	5·72	29·42	5·85	29·40	5·98	29·37	6·11	30
31	30·43	5·92	30·40	6·05	30·38	6·18	30·35	6·31	31
32	31·41	6·11	31·39	6·24	31·36	6·38	31·33	6·52	32
33	32·39	6·30	32·37	6·44	32·34	6·58	32·31	6·72	33
34	33·38	6·49	33·35	6·63	33·32	6·78	33·29	6·92	34
35	34·36	6·68	34·33	6·83	34·30	6·98	34·27	7·13	35
36	35·34	6·87	35·31	7·02	35·28	7·18	35·25	7·33	36
37	36·32	7·06	36·29	7·22	36·26	7·38	36·22	7·53	37
38	37·30	7·25	37·27	7·41	37·24	7·58	37·20	7·74	38
39	38·28	7·44	38·25	7·61	38·22	7·78	38·18	7·94	39
40	39·27	7·63	39·23	7·80	39·20	7·97	39·16	8·15	40
41	40·25	7·82	40·21	8·00	40·18	8·17	40·14	8·35	41
42	41·23	8·01	41·19	8·19	41·16	8·37	41·12	8·55	42
43	42·21	8·20	42·17	8·39	42·14	8·57	42·10	8·76	43
44	43·19	8·40	43·15	8·58	43·12	8·77	43·08	8·96	44
45	44·17	8·59	44·14	8·78	44·10	8·97	44·06	9·16	45
46	45·15	8·78	45·12	8·97	45·08	9·17	45·04	9·37	46
47	46·14	8·97	46·10	9·17	46·06	9·37	46·02	9·57	47
48	47·12	9·16	47·08	9·36	47·04	9·57	46·99	9·78	48
49	48·10	9·35	48·06	9·56	48·02	9·77	47·97	9·98	49
50	49·08	9·54	49·04	9·75	49·00	9·97	48·95	10·18	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	79 Deg.		78¾ Deg.		78½ Deg.		78¼ Deg.		

Distance.	11 Deg. Lat.	11 Deg. Dep.	11¼ Deg. Lat.	11¼ Deg. Dep.	11½ Deg. Lat.	11½ Deg. Dep.	11¾ Deg. Lat.	11¾ Deg. Dep.	Distance.
51	50·06	9·73	50·02	9·95	49·98	10·17	49·93	10·39	51
52	51·04	9·92	51·00	10·14	50·96	10·37	50·91	10·59	52
53	52·03	10·11	51·98	10·34	51·94	10·57	51·89	10·79	53
54	53·01	10·30	52·96	10·53	52·92	10·77	52·87	11·00	54
55	53·99	10·49	53·94	10·73	53·90	10·97	53·85	11·20	55
56	54·97	10·69	54·92	10·93	54·88	11·16	54·83	11·40	56
57	55·95	10·88	55·90	11·12	55·86	11·36	55·81	11·61	57
58	56·93	11·07	56·89	11·32	56·84	11·56	56·78	11·81	58
59	57·92	11·26	57·87	11·51	57·82	11·76	57·76	12·01	59
60	58·90	11·45	58·85	11·71	58·80	11·96	58·74	12·22	60
61	59·88	11·64	59·83	11·90	59·78	12·16	59·72	12·42	61
62	60·86	11·83	60·81	12·10	60·76	12·36	60·70	12·63	62
63	61·84	12·02	61·79	12·29	61·74	12·56	61·68	12·83	63
64	62·82	12·21	62·77	12·49	62·72	12·76	62·66	13·03	64
65	63·81	12·40	63·75	12·68	63·70	12·96	63·64	13·24	65
66	64·79	12·59	64·73	12·88	64·68	13·16	64·62	13·44	66
67	65·77	12·78	65·71	13·07	65·66	13·36	65·60	13·64	67
68	66·75	12·98	66·69	13·27	66·63	13·56	66·58	13·85	68
69	67·73	13·17	67·67	13·46	67·61	13·76	67·55	14·05	69
70	68·71	13·36	68·66	13·66	68·59	13·96	68·53	14·25	70
71	69·70	13·55	69·64	13·85	69·57	14·16	69·51	14·46	71
72	70·68	13·74	70·62	14·05	70·55	14·35	70·49	14·66	72
73	71·66	13·93	71·60	14·24	71·53	14·55	71·47	14·87	73
74	72·64	14·12	72·58	14·44	72·51	14·75	72·45	15·07	74
75	73·62	14·31	73·56	14·63	73·49	14·95	73·43	15·27	75
76	74·60	14·50	74·54	14·83	74·47	15·15	74·41	15·48	76
77	75·59	14·69	75·52	15·02	75·45	15·35	75·39	15·68	77
78	76·57	14·88	76·50	15·22	76·43	15·55	76·37	15·88	78
79	77·55	15·07	77·48	15·41	77·41	15·75	77·34	16·09	79
80	78·53	15·26	78·46	15·61	78·39	15·95	78·32	16·29	80
81	79·51	15·46	79·44	15·80	79·37	16·15	79·30	16·49	81
82	80·49	15·65	80·42	16·00	80·35	16·35	80·28	16·70	82
83	81·48	15·84	81·41	16·19	81·33	16·55	81·26	16·90	83
84	82·46	16·03	82·39	16·39	82·31	16·75	82·24	17·11	84
85	83·44	16·22	83·37	16·58	83·29	16·95	83·22	17·31	85
86	84·42	16·41	84·35	16·78	84·27	17·15	84·20	17·51	86
87	85·40	16·60	85·33	16·97	85·25	17·35	85·18	17·72	87
88	86·38	16·79	86·31	17·17	86·23	17·54	86·16	17·92	88
89	87·36	16·98	87·29	17·36	87·21	17·74	87·14	18·12	89
90	88·35	17·17	88·27	17·56	88·19	17·94	88·11	18·33	90
91	89·33	17·36	89·25	17·75	89·17	18·14	89·09	18·53	91
92	90·31	17·55	90·23	17·95	90·15	18·34	90·07	18·74	92
93	91·29	17·75	91·21	18·14	91·13	18·54	91·05	18·94	93
94	92·27	17·94	92·19	18·34	92·11	18·74	92·03	19·14	94
95	93·25	18·13	93·17	18·53	93·09	18·94	93·01	19·35	95
96	94·24	18·32	94·16	18·73	94·07	19·14	93·99	19·55	96
97	95·22	18·51	95·14	18·92	95·05	19·34	94·97	19·75	97
98	96·20	18·70	96·12	19·12	96·03	19·54	95·95	19·96	98
99	97·18	18·89	97·10	19·31	97·01	19·74	96·93	20·16	99
100	98·16	19·08	98·08	19·51	97·99	19·94	97·90	20·36	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	79 Deg.		78¾ Deg.		78½ Deg.		78¼ Deg.		

Distance.	12 Deg.		12¼ Deg.		12½ Deg.		12¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·98	0·21	0·98	0·21	0·98	0·22	0·98	0·22	1
2	1·96	0·42	1·95	0·42	1·95	0·43	1·95	0·44	2
3	2·93	0·62	2·93	0·64	2·93	0·65	2·93	0·66	3
4	3·91	0·83	3·91	0·85	3·91	0·87	3·90	0·88	4
5	4·89	1·04	4·89	1·06	4·88	1·08	4·88	1·10	5
6	5·87	1·25	5·86	1·27	5·86	1·30	5·85	1·32	6
7	6·85	1·46	6·84	1·49	6·83	1·52	6·83	1·54	7
8	7·83	1·66	7·82	1·70	7·81	1·73	7·80	1·77	8
9	8·80	1·87	8·80	1·91	8·79	1·95	8·78	1·99	9
10	9·78	2·08	9·77	2·12	9·76	2·16	9·75	2·21	10
11	10·76	2·29	10·75	2·33	10·74	2·38	10·73	2·43	11
12	11·74	2·49	11·73	2·55	11·72	2·60	11·70	2·65	12
13	12·72	2·70	12·70	2·76	12·69	2·81	12·68	2·87	13
14	13·69	2·91	13·68	2·97	13·67	3·03	13·65	3·09	14
15	14·67	3·12	14·66	3·18	14·64	3·25	14·63	3·31	15
16	15·65	3·33	15·64	3·39	15·62	3·46	15·61	3·53	16
17	16·63	3·53	16·61	3·61	16·60	3·68	16·58	3·75	17
18	17·61	3·74	17·59	3·82	17·57	3·90	17·56	3·97	18
19	18·58	3·95	18·57	4·03	18·55	4·11	18·53	4·19	19
20	19·56	4·16	19·54	4·24	19·53	4·33	19·51	4·41	20
21	20·54	4·37	20·52	4·46	20·50	4·55	20·48	4·63	21
22	21·52	4·57	21·50	4·67	21·48	4·76	21·46	4·86	22
23	22·50	4·78	22·48	4·88	22·45	4·98	22·43	5·08	23
24	23·48	4·99	23·45	5·09	23·43	5·19	23·41	5·30	24
25	24·45	5·20	24·43	5·30	24·41	5·41	24·38	5·52	25
26	25·43	5·41	25·41	5·52	25·38	5·63	25·36	5·74	26
27	26·41	5·61	26·39	5·73	26·36	5·84	26·33	5·96	27
28	27·39	5·82	27·36	5·94	27·34	6·06	27·31	6·18	28
29	28·37	6·03	28·34	6·15	28·31	6·28	28·28	6·40	29
30	29·34	6·24	29·32	6·37	29·29	6·49	29·26	6·62	30
31	30·32	6·45	30·29	6·58	30·27	6·71	30·24	6·84	31
32	31·30	6·65	31·27	6·79	31·24	6·93	31·21	7·06	32
33	32·28	6·86	32·25	7·00	32·22	7·14	32·19	7·28	33
34	33·26	7·07	33·23	7·21	33·19	7·36	33·16	7·50	34
35	34·24	7·28	34·20	7·43	34·17	7·58	34·14	7·72	35
36	35·21	7·48	35·18	7·64	35·15	7·79	35·11	7·95	36
37	36·19	7·69	36·16	7·85	36·12	8·01	36·09	8·17	37
38	37·17	7·90	37·13	8·06	37·10	8·22	37·06	8·39	38
39	38·15	8·11	38·11	8·27	38·08	8·44	38·04	8·61	39
40	39·13	8·32	39·09	8·49	39·05	8·66	39·01	8·83	40
41	40·10	8·52	40·07	8·70	40·03	8·87	39·99	9·05	41
42	41·08	8·73	41·04	8·91	41·00	9·09	40·96	9·27	42
43	42·06	8·94	42·02	9·12	41·98	9·31	41·94	9·49	43
44	43·04	9·15	43·00	9·34	42·96	9·52	42·92	9·71	44
45	44·02	9·36	43·98	9·55	43·93	9·74	43·89	9·93	45
46	44·99	9·56	44·95	9·76	44·91	9·96	44·87	10·15	46
47	45·97	9·77	45·93	9·97	45·89	10·17	45·84	10·37	47
48	46·95	9·98	46·91	10·18	46·86	10·39	46·82	10·59	48
49	47·93	10·19	47·88	10·40	47·84	10·61	47·79	10·81	49
50	48·91	10·40	48·86	10·61	48·81	10·82	48·77	11·03	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	78 Deg.		77¾ Deg.		77½ Deg.		77¼ Deg.		

Distance.	12 Deg.		12¼ Deg.		12½ Deg.		12¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	49·89	10·60	49·84	10·82	49·79	11·04	49·74	11·26	51
52	50·86	10·81	50·82	11·03	50·77	11·25	50·72	11·48	52
53	51·84	11·02	51.79	11·25	51·74	11·47	51·69	11·70	53
54	52·82	11·23	52·77	11·46	52.72	11·69	52·67	11·92	54
55	53·80	11·44	53·75	11·67	53·70	11·90	53·64	12·14	55
56	54·78	11·64	54·72	11·88	54·67	12·12	54·62	12·36	56
57	55·75	11·85	55·70	12·09	55·65	12.34	55·59	12·58	57
58	56·73	12·06	56·68	12·31	56·63	12·55	56·57	12·80	58
59	57·71	12·27	57·66	12·52	57·60	12·77	57·55	13·02	59
60	58·69	12·47	58·63	12·73	58·58	12·99	58·52	13·24	60
61	59·67	12·68	59·61	12·94	59·55	13·20	59·50	13·46	61
62	60·65	12·89	60·59	13·16	60·53	13·42	60·47	13·68	62
63	61·62	13·10	61·57	13·37	61·51	13·64	61·45	13·90	63
64	62·60	13·31	62·54	13·58	62·48	13·85	62·42	14·12	64
65	63·58	13·51	63·52	13·79	63·46	14·07	63·40	14·35	65
66	64·56	13·72	64·50	14·00	64·44	14·29	64·37	14·57	66
67	65·54	13·93	65·47	14·22	65·41	14·50	65·35	14·79	67
68	66·51	14·14	66·45	14·43	66·39	14·72	66·32	15·01	68
69	67·49	14·35	67·43	14·64	67·36	14·93	67·30	15·23	69
70	68·47	14·55	68·41	14·85	68·34	15·15	68·27	15·45	70
71	69·45	14·76	69·38	15·06	69·32	15·37	69·25	15·67	71
72	70·43	14·97	70·36	15·28	70·29	15·58	70·22	15·89	72
73	71·40	15·18	71·34	15·49	71·27	15·80	71·20	16·11	73
74	72·38	15·39	72·32	15·70	72·25	16·02	72·18	16·33	74
75	73·36	15·59	73·29	15·91	73·22	16·23	73·15	16·55	75
76	74·34	15·80	74·27	16·13	74·20	16·45	74·13	16·77	76
77	75·32	16·01	75·25	16·34	75·17	16·67	75·10	16·99	77
78	76·30	16·22	76·22	16·55	76·15	16·88	76·08	17·21	78
79	77·27	16·43	77·20	16·76	77·13	17·10	77·05	17·44	79
80	78·25	16·63	78·18	16·97	78·10	17·32	78·03	17·66	80
81	79·23	16·84	79·16	17·19	79·08	17·53	79·00	17·88	81
82	80·21	17·05	80·13	17·40	80·06	17·75	79·98	18·10	82
83	81·19	17·26	81·11	17·61	81·03	17·96	80·95	18·32	83
84	82·16	17·46	82·09	17·82	82·01	18·18	81·93	18·54	84
85	83·14	17·67	83·06	18·04	82·99	18·40	82·90	18·76	85
86	84·12	17·88	84·04	18·25	83·96	18·61	83·88	18·98	86
87	85·10	18·09	85·02	18·46	84·94	18·83	84·85	19·20	87
88	86·08	18·30	86·00	18·67	85·91	19·05	85·83	19·42	88
89	87·06	18·50	86·97	18·88	86·89	19·26	86·81	19·64	89
90	88·03	18·71	87·95	19·10	87·87	19·48	87·78	19·86	90
91	89·01	18·92	88·93	19·31	88·84	19·70	88·76	20·08	91
92	89·99	19·13	89·91	19·52	89·82	19·91	89·73	20·30	92
93	90·97	19·34	90·88	19·73	90·80	20·13	90·71	20·52	93
94	91·95	19·54	91·86	19·94	91·77	20·35	91·68	20·75	94
95	92·92	19·75	92·84	20·16	92·75	20·56	92·66	20·97	95
96	93·90	19·96	93·81	20·37	93·72	20·78	93·63	21·19	96
97	94·88	20·17	94·79	20·58	94·70	20·99	94·61	21·41	97
98	95·86	20·38	95·77	20·79	95·68	21·21	95·58	21·63	98
99	96·84	20·58	96·75	21·01	96·65	21·43	96·56	21·85	99
100	97·81	20·79	97·72	21·22	97·63	21·64	97.53	22·07	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	78 Deg.		77¾ Deg.		77½ Deg.		77¼ Deg.		

Distance.	13 Deg.		13¼ Deg.		13½ Deg.		13¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·97	0·23	0·97	0·23	0·97	0·23	0·97	0·24	1
2	1·95	0·45	1·95	0·46	1·95	0·47	1·94	0·48	2
3	2·92	0·67	2·92	0·69	2·92	0·70	2·91	0·71	3
4	3·90	0·90	3·89	0·92	3·89	0·93	3·89	0·95	4
5	4·87	1·12	4·87	1·15	4·86	1·17	4·86	1·19	5
6	5·85	1·35	5·84	1·38	5·83	1·40	5·83	1·43	6
7	6·82	1·57	6·81	1·60	6·81	1·63	6·80	1·66	7
8	7·80	1·80	7·79	1·83	7·78	1·87	7·77	1·90	8
9	8·77	2·02	8·76	2·06	8·75	2·10	8·74	2·14	9
10	9·74	2·25	9·73	2·29	9·72	2·33	9·71	2·38	10
11	10·72	2·47	10·71	2·52	10·70	2·57	10·68	2·61	11
12	11·69	2·70	11·68	2·75	11·67	2·80	11·66	2·85	12
13	12·67	2·92	12·65	2·98	12·64	3·03	12·63	3·09	13
14	13·64	3·15	13·63	3·21	13·61	3·27	13·60	3·33	14
15	14·62	3·37	14·60	3·44	14·59	3·50	14·57	3·57	15
16	15·59	3·60	15·57	3·67	15·56	3·74	15·54	3·80	16
17	16·57	3·82	16·55	3·90	16·53	3·97	16·51	4·04	17
18	17·54	4·05	17·52	4·13	17·50	4·20	17·48	4·28	18
19	18·51	4·27	18·49	4·35	18·48	4·44	18·46	4·52	19
20	19·49	4·50	19·47	4·58	19·45	4·67	19·43	4·75	20
21	20·46	4·72	20·44	4·81	20·42	4·90	20·40	4·99	21
22	21·44	4·95	21·41	5·04	21·39	5·14	21·37	5·23	22
23	22·41	5·17	22·39	5·27	22·36	5·37	22·34	5·47	23
24	23·38	5·40	23·36	5·50	23·34	5·60	23·31	5·70	24
25	24·36	5·62	24·33	5·73	24·31	5·84	24·28	5·94	25
26	25·33	5·85	25·31	5·96	25·28	6·07	25·25	6·18	26
27	26·31	6·07	26·28	6·19	26·25	6·30	26·23	6·42	27
28	27·28	6·30	27·25	6·42	27·23	6·54	27·20	6·66	28
29	28·26	6·52	28·23	6·65	28·20	6·77	28·17	6·89	29
30	29·23	6·75	29·20	6·88	29·17	7·00	29·14	7·13	30
31	30·21	6·97	30·17	7·11	30·14	7·24	30·11	7·37	31
32	31·18	7·20	31·15	7·33	31·12	7·47	31·08	7·61	32
33	32·15	7·42	32·12	7·56	32·09	7·70	32·05	7·84	33
34	33·13	7·65	33·09	7·79	33·06	7·94	33·03	8·08	34
35	34·10	7·87	34·07	8·02	34·03	8·17	34·00	8·32	35
36	35·08	8·10	35·04	8·25	35·01	8·40	34·97	8·56	36
37	36·05	8·32	36·02	8·48	35·98	8·64	35·94	8·79	37
38	37·03	8·55	36·99	8·71	36·95	8·87	36·91	9·03	38
39	38·00	8·77	37·96	8·94	37·92	9·10	37·88	9·27	39
40	38·97	9·00	38·94	9·17	38·89	9·34	38·85	9·51	40
41	39·95	9·22	39·91	9·40	39·87	9·57	39·83	9·75	41
42	40·92	9·45	40·88	9·63	40·84	9·80	40·80	9·98	42
43	41·90	9·67	41·86	9·86	41·81	10·04	41·77	10·22	43
44	42·87	9·90	42·83	10·08	42·78	10·27	42·74	10·46	44
45	43·85	10·12	43·80	10·31	43·76	10·51	43·71	10·70	45
46	44·82	10·35	44·78	10·54	44·73	10·74	44·68	10·93	46
47	45·80	10·57	45·75	10·77	45·70	10·97	45·65	11·17	47
48	46·77	10·80	46·72	11·00	46·67	11·21	46·62	11·41	48
49	47·74	11·02	47·70	11·23	47·65	11·44	47·60	11·65	49
50	48·72	11·25	48·67	11·46	48·62	11·67	48·57	11·88	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	77 Deg.		76¾ Deg.		76½ Deg.		76¼ Deg.		

Distance.	13 Deg.		13¼ Deg.		13½ Deg.		13¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	49·69	11·47	49·64	11·69	49·59	11·91	49·54	12·12	51
52	50·67	11·70	50·62	11·92	50·56	12·14	50·51	12·36	52
53	51·64	11·92	51·59	12·15	51·54	12·37	51·48	12·60	53
54	52·62	12·15	52·56	12·38	52·51	12·61	52·45	12·84	54
55	53·59	12·37	53·54	12·61	53·48	12·84	53·42	13·07	55
56	54·56	12·60	54·51	12·84	54·45	13·07	54·40	13·31	56
57	55·54	12·82	55·48	13·06	55·43	13·31	55·37	13·55	57
58	56·51	13·05	56·46	13·29	56·40	13·54	56·34	13·79	58
59	57·49	13·27	57·43	13·52	57·37	13·77	57·31	14·02	59
60	58·46	13·50	58·40	13·75	58·34	14·01	58·28	14·26	60
61	59·44	13·72	59·38	13·98	59·31	14·24	59·25	14·50	61
62	60·41	13·95	60·35	14·21	60·29	14·47	60·22	14·74	62
63	61·39	14·17	61·32	14·44	61·26	14·71	61·19	14·97	63
64	62·36	14·40	62·30	14·67	62·23	14·94	62·17	15·21	64
65	63·33	14·62	63·27	14·90	63·20	15·17	63·14	15·45	65
66	64·31	14·85	64·24	15·13	64·18	15·41	64·11	15·69	66
67	65·28	15·07	65·22	15·36	65·15	15·64	65·08	15·93	67
68	66·26	15·30	66·19	15·59	66·12	15·87	66·05	16·16	68
69	67·23	15·52	67·16	15·81	67·09	16·11	67·02	16·40	69
70	68·21	15·75	68·14	16·04	68·07	16·34	67·99	16·64	70
71	69·18	15·97	69·11	16·27	69·04	16·57	68·97	16·88	71
72	70·15	16·20	70·08	16·50	70·01	16·81	69·94	17·11	72
73	71·13	16·42	71·06	16·73	70·98	17·04	70·91	17·35	73
74	72·10	16·65	72·03	16·96	71·96	17·28	71·88	17·59	74
75	73·08	16·87	73·00	17·19	72·93	17·50	72·85	17·83	75
76	74·05	17·10	73·98	17·42	73·90	17·74	73·82	18·06	76
77	75·03	17·32	74·95	17·65	74·87	17·98	74·79	18·30	77
78	76·00	17·55	75·92	17·88	75·84	18·21	75·76	18·54	78
79	76·98	17·77	76·90	18·11	76·82	18·44	76·74	18·78	79
80	77·95	18·00	77·87	18·34	77·79	18·68	77·71	19·01	80
81	78·92	18·22	78·84	18·57	78·76	18·91	78·68	19·25	81
82	79·90	18·45	79·82	18·79	79·73	19·14	79·65	19·49	82
83	80·87	18·67	80·79	19·02	80·71	19·38	80·62	19·73	83
84	81·85	18·90	81·76	19·25	81·68	19·61	81·59	19·97	84
85	82·82	19·12	82·74	19·48	82·65	19·84	82·56	20·20	85
86	83·80	19·35	83·71	19·71	83·62	20·08	83·54	20·44	86
87	84·77	19·57	84·68	19·94	84·60	20·31	84·51	20·68	87
88	85·74	19·80	85·66	20·17	85·57	20·54	85·48	20·92	88
89	86·72	20·02	86·63	20·40	86·54	20·78	86·45	21·15	89
90	87·69	20·25	87·60	20·63	87·51	21·01	87·42	21·39	90
91	88·67	20·47	88·58	20·86	88·49	21·24	88·39	21·63	91
92	89·64	20·70	89·55	21·09	89·46	21·48	89·36	21·87	92
93	90·62	20·92	90·52	21·32	90·43	21·71	90·33	22·10	93
94	91·59	21·15	91·50	21·54	91·40	21·94	91·31	22·34	94
95	92·57	21·37	92·47	21·77	92·38	22·18	92·28	22·58	95
96	93·54	21·60	93·44	22·00	93·35	22·41	93·25	22·82	96
97	94·51	21·82	94·42	22·23	94·32	22·64	94·22	23·06	97
98	95·49	22·05	95·39	22·46	95·29	22·88	95·19	23·29	98
99	96·46	22·27	96·36	22·69	96·26	23·11	96·16	23·53	99
100	97·44	22·50	97·34	22·92	97·24	23·34	97·13	23·77	100
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
Distance.	77 Deg.		76¾ Deg.		76½ Deg.		76¼ Deg.		Distance.

Distance.	14 Deg.		14¼ Deg.		14½ Deg.		14¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·97	0·24	0·97	0·25	0·97	0·25	0·97	0·25	1
2	1·94	0·48	1·94	0·49	1·94	0·50	1·93	0·51	2
3	2·91	0·73	2·91	0·74	2·90	0·75	2·90	0·76	3
4	3·88	0·97	3·88	0·98	3·87	1·00	3·97	1·02	4
5	4·85	1·21	4·85	1·23	4·84	1·25	4·84	1·27	5
6	5·82	1·45	5·82	1·48	5·81	1·50	5·80	1·53	6
7	6·79	1·69	6·78	1·72	6·78	1·75	6·77	1·78	7
8	7·76	1·94	7·75	1·97	7·75	2·00	7·74	2·04	8
9	8·73	2·18	8·72	2·22	8·71	2·25	8·70	2·29	9
10	9·70	2·42	9·69	2·46	9·68	2·50	9·67	2·55	10
11	10·67	2·66	10·66	2·71	10·65	2·75	10·64	2·80	11
12	11·64	2·90	11·63	2·95	11·62	3·00	11·60	3·06	12
13	12·61	3·15	12·60	3·20	12·59	3·25	12·57	3·31	13
14	13·58	3·39	13·57	3·45	13·55	3·51	13·54	3·56	14
15	14·55	3·63	14·54	3·69	14·52	3·76	14·51	3·82	15
16	15·52	3·87	15·51	3·94	15·49	4·01	15·47	4·07	16
17	16·50	4·11	16·48	4·18	16·46	4·26	16·44	4·33	17
18	17·47	4·35	17·45	4·43	17·43	4·51	17·41	4·58	18
19	18·44	4·60	18·42	4·68	18·39	4·76	18·37	4·84	19
20	19·41	4·84	19·38	4·92	19·36	5·01	19·34	5·09	20
21	20·38	5·08	20·35	5·17	20·33	5·26	20·31	5·35	21
22	21·35	5·32	21·32	5·42	21·30	5·51	21·28	5·60	22
23	22·32	5·56	22·29	5·66	22·27	5·76	22·24	5·86	23
24	23·29	5·81	23·26	5·91	23·24	6·01	23·21	6·11	24
25	24·26	6·05	24·23	6·15	24·20	6·26	24·18	6·37	25
26	25·23	6·29	25·20	6·40	25·17	6·51	25·14	6·62	26
27	26·20	6·53	26·17	6·65	26·14	6·76	26·11	6·87	27
28	27·17	6·77	27·14	6·89	27·11	7·01	27·08	7·13	28
29	28·14	7·02	28·11	7·14	28·08	7·26	28·04	7·38	29
30	29·11	7·26	29·08	7·38	29·04	7·51	29·01	7·64	30
31	30·08	7·50	30·05	7·63	30·01	7·76	29·98	7·89	31
32	31·05	7·74	31·02	7·88	30·98	8·01	30·95	8·15	32
33	32·02	7·98	31·98	8·12	31·95	8·26	31·91	8·40	33
34	32·99	8·23	32·95	8·37	32·92	8·51	32·88	8·66	34
35	33·96	8·47	33·92	8·62	33·89	8·76	33·85	8·91	35
36	34·93	8·71	34·89	8·86	34·85	9·01	34·81	9·17	36
37	35·90	8·95	35·86	9·11	35·82	9·26	35·78	9·42	37
38	36·87	9·19	36·83	9·35	36·79	9·51	36·75	9·67	38
39	37·84	9·44	37·80	9·60	37·76	9·76	37·71	9·93	39
40	38·81	9·68	38·77	9·85	38·73	10·02	38·68	10·18	40
41	39·78	9·92	39·74	10·09	39·69	10·27	39·65	10·44	41
42	40·75	10·16	40·71	10·34	40·66	10·52	40·62	10·69	42
43	41·72	10·40	41·68	10·58	41·63	10·77	41·58	10·95	43
44	42·69	10·64	42·65	10·83	42·60	11·02	42·55	11·20	44
45	43·66	10·89	43·62	11·08	43·57	11·27	43·52	11·46	45
46	44·63	11·13	44·58	11·32	44·53	11·52	44·48	11·71	46
47	45·60	11·37	45·55	11·57	45·50	11·77	45·45	11·97	47
48	46·57	11·61	46·52	11·82	46·47	12·02	46·42	12·22	48
49	47·54	11·85	47·49	12·06	47·44	12·27	47·39	12·48	49
50	48·51	12·10	48·46	12·31	48·41	12·52	48·35	12·73	50
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
Distance.	76 Deg.		75¾ Deg.		75½ Deg.		75¼ Deg.		Distance.

Distance.	14 Deg. Lat.	14 Deg. Dep.	14¼ Deg. Lat.	14¼ Deg. Dep.	14½ Deg. Lat.	14½ Deg. Dep.	14¾ Deg. Lat.	14¾ Deg. Dep.	Distance.
51	49·49	12·34	49·43	12·55	49·38	12·77	49·32	12·98	51
52	50·46	12·58	50·40	12·80	50·34	13·02	50·29	13·24	52
53	51·43	12·82	51·37	13·05	51·31	13·27	51·25	13·49	53
54	52·40	13·06	52·34	13·29	52·28	13·52	52·22	13·75	54
55	53·37	13·31	53·31	13·54	53·25	13·77	53·19	14·00	55
56	54·34	13·55	54·28	13·78	54·22	14·02	54·15	14·26	56
57	55·31	13·79	55·25	14·03	55·18	14·27	55·12	14·51	57
58	56·28	14·03	56·22	14·28	56·15	14·52	56·09	14·77	58
59	57·25	14·27	57·18	14·52	57·12	14·77	57·06	15·02	59
60	58·22	14·52	58·15	14·77	58·09	15·02	58·02	15·28	60
61	59·19	14·76	59·12	15·02	59·06	15·27	58·99	15·53	61
62	60·16	15·00	60·09	15·26	60·03	15·52	59·96	15·79	62
63	61·13	15·24	61·06	15·51	60·99	15 77	60·92	16·04	63
64	62·10	15·48	62·03	15·75	61·96	16·02	61·89	16·29	64
65	63·07	15·72	63·00	16·00	62·93	16·27	62·86	16·55	65
66	64·04	15·97	63·97	16·25	63·90	16·53	63·83	16·80	66
67	65·01	16·21	64·94	16·49	64·87	16·78	64·79	17·06	67
68	65·98	16·45	65·91	16·74	65·83	17·03	65·76	17·31	68
69	66·95	16·69	66·88	16·98	66·80	17·28	66·73	17·57	69
70	67·92	16·93	67·85	17·23	67·77	17·53	67·69	17·82	70
71	68·89	17·18	68·82	17·48	68·74	17·78	68·66	18·08	71
72	69·86	17·42	69·78	17·72	69·71	18·03	69·63	18·33	72
73	70·83	17·66	70·75	17·97	70·67	18·28	70·59	18·59	73
74	71·80	17·90	71·72	18·22	71·64	18·53	71·56	18·84	74
75	72·77	18·14	72·69	18·46	72·61	18·78	72·53	19·10	75
76	73·74	18·39	73·66	18·71	73·58	19·03	73·50	19·35	76
77	74·71	18·63	74·63	18·95	74·55	19·28	74·46	19·60	77
78	75·68	18·87	75·60	19·20	75·52	19·53	75·43	19·86	78
79	76·65	19·11	76·57	19·45	76·48	19·78	76·40	20·11	79
80	77·62	19·35	77·54	19·69	77·45	20·03	77·36	20·37	80
81	78·59	19·60	78·51	19·94	78·42	20·28	78·33	20·62	81
82	79·56	19·84	79·48	20·18	79·39	20·53	79·30	20·88	82
83	80·53	20·08	80·45	20·43	80·36	20·78	80·26	21·13	83
84	81·50	20·32	81·42	20·68	81·32	21·03	81·23	21·39	84
85	82·48	20·56	82·38	20·92	82·29	21·28	82·20	21·64	85
86	83·45	20·81	83·35	21·17	83·26	21·53	83·17	21·90	86
87	84·42	21·05	84·32	21·42	84·23	21·78	84·13	22·15	87
88	85·39	21·29	85·29	21·66	85·20	22·03	85·10	22·41	88
89	86·36	21·53	86·26	21·91	86·17	22·28	86·07	22·66	89
90	87·33	21·77	87·23	22·15	87·13	22·53	87·03	22·91	90
91	88·30	22·01	88·20	22·40	88·10	22·78	88·00	23·17	91
92	89·27	22·26	89·17	22.65	89·07	23·04	88·97	23·42	92
93	90·24	22·50	90·14	22·89	90·04	23·29	89·94	23·68	93
94	91·21	22·74	91·11	23·14	91·01	23·54	90·90	23·93	94
95	92·18	22·98	92·08	23·38	91·97	23·79	91·87	24·19	95
96	93·15	23·22	93·05	23·63	92·94	24·04	92·84	24·44	96
97	94·12	23·47	94·02	23·88	93·91	24·29	93·80	24·70	97
98	95·09	23·71	94·98	24·12	94·88	24·54	94·77	24·95	98
99	96·06	23·95	95·95	24·37	95·85	24·79	95·74	25·21	99
100	97·03	24·19	96·92	24·62	96·81	25·04	96·70	25·46	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	76 Deg.		75¾ Deg.		75½ Deg.		75¼ Deg.		

Distance.	15 Deg.		15¼ Deg.		15½ Deg.		15¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·97	0·26	0·96	0·26	0·96	0·27	0·96	0·27	1
2	1·93	0·52	1·93	0·53	1·93	0·53	1·92	0·54	2
3	2·90	0·78	2·89	0·79	2·89	0·80	2·89	0·81	3
4	3·86	1·04	3·86	1·05	3·85	1·07	3·85	1·09	4
5	4·83	1·29	4·82	1·32	4·82	1·34	4·81	1·36	5
6	5·80	1·55	5·79	1·58	5·78	1·60	5·77	1·63	6
7	6·76	1·81	6·75	1·84	6·75	1·87	6·74	1·90	7
8	7·73	2·07	7·72	2·10	7·71	2·14	7·70	2·17	8
9	8·69	2·33	8·68	2·37	8·67	2·41	8·66	2·44	9
10	9·66	2·59	9·65	2·63	9·64	2·67	9·62	2·71	10
11	10·63	2·85	10·61	2·89	10·60	2·94	10·59	2·99	11
12	11·59	3·11	11·58	3·16	11·56	3·21	11·55	3·26	12
13	12·56	3·36	12·54	3·42	12·53	3·47	12·51	3·53	13
14	13·52	3·62	13·51	3·68	13·49	3·74	13·47	3·80	14
15	14·49	3·88	14·47	3·95	14·45	4·01	14·44	4·07	15
16	15·45	4·14	15·44	4·21	15·42	4·28	15·40	4·34	16
17	16·42	4·40	16·40	4·47	16·38	4·54	16·36	4·61	17
18	17·39	4·66	17·37	4·73	17·35	4·81	17·32	4·89	18
19	18·35	4·92	18·33	5·00	18·31	5·08	18·29	5·16	19
20	19·32	5·18	19·30	5·26	19·27	5·34	19·25	5·43	20
21	20·28	5·44	20·26	5·52	20·24	5·61	20·21	5·70	21
22	21·25	5·69	21·23	5·79	21·20	5·88	21·17	5·97	22
23	22·22	5·95	22·19	6·05	22·16	6·15	22·14	6·24	23
24	23·18	6·21	23·15	6·31	23·13	6·41	23·10	6·51	24
25	24·15	6·47	24·12	6·58	24·09	6·68	24·06	6·79	25
26	25·11	6·73	25·08	6·84	25·05	6·95	25·02	7·06	26
27	26·08	6·99	26·05	7·10	26·02	7·22	25·99	7·33	27
28	27·05	7·25	27·01	7·36	26·98	7·48	26·95	7·60	28
29	28·01	7·51	27·98	7·63	27·95	7·75	27·91	7·87	29
30	28·98	7·76	28·94	7·89	28·91	8·02	28·87	8·14	30
31	29·94	8·02	29·91	8·15	29·87	8·28	29·84	8·41	31
32	30·91	8·28	30·87	8·42	30·84	8·55	30·80	8·69	32
33	31·88	8·54	31·84	8·68	31·80	8·82	31·76	8·96	33
34	32·84	8·80	32·80	8·94	32·76	9·09	32·72	9·23	34
35	33·81	9·06	33·77	9·21	33·73	9·35	33·69	9·50	35
36	34·77	9·32	34·73	9·47	34·69	9·62	34·65	9·77	36
37	35·74	9·58	35·70	9·73	35·65	9·89	35·61	10·04	37
38	36·71	9·84	36·66	10·00	36·62	10·16	36·57	10·31	38
39	37·67	10·09	37·63	10·26	37·58	10·42	37·54	10·59	39
40	38·64	10·35	38·59	10·52	38·55	10·69	38·50	10·86	40
41	39·60	10·61	39·56	10·78	39·51	10·96	39·46	11·13	41
42	40·57	10·87	40·52	11·05	40·47	11·22	40·42	11·40	42
43	41·53	11·13	41·49	11·31	41·44	11·49	41·39	11·67	43
44	42·50	11·39	42·45	11·57	42·40	11·76	42·35	11·94	44
45	43·47	11·65	43·42	11·84	43·36	12·03	43·31	12·21	45
46	44·43	11·91	44·38	12·10	44·33	12·29	44·27	12·49	46
47	45·40	12·16	45·35	12·36	45·29	12·56	45·24	12·76	47
48	46·36	12·42	46·31	12·63	46·25	12·83	46·20	13·03	48
49	47·33	12·68	47·27	12·89	47·22	13·09	47·16	13·30	49
50	48·30	12·94	48·24	13·15	48·18	13·36	48·12	13·57	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	75 Deg.		74¾ Deg.		74½ Deg.		74¼ Deg.		

Distance.	15 Deg. Lat.	15 Deg. Dep.	15¼ Deg. Lat.	15¼ Deg. Dep.	15½ Deg. Lat.	15½ Deg. Dep.	15¾ Deg. Lat.	15¾ Deg. Dep.	Distance.
51	49·26	13·20	49·20	13·41	49·15	13·63	49·09	13·84	51
52	50·23	13·46	50·17	13·68	50·11	13·90	50·05	14·11	52
53	51·19	13·72	51·13	13·94	51·07	14·16	51·01	14·39	53
54	52·16	13·98	52·10	14·20	52·04	14·43	51·97	14·66	54
55	53·13	14·24	53·06	14·47	53·00	14·70	52·94	14·93	55
56	54·09	14·49	54·03	14·73	53·96	14·97	53·90	15·20	56
57	55·06	14·75	54·99	14·99	54·93	15·23	54·86	15·47	57
58	56·02	15·01	55·96	15·26	55·89	15·50	55·82	15·74	58
59	56·99	15·27	56·92	15·52	56·85	15·77	56·78	16·01	59
60	57·96	15·53	57·89	15·78	57·82	16·03	57·75	16·29	60
61	58·92	15·79	58·85	16·04	58·78	16·30	58·71	16·56	61
62	59·89	16·05	59·82	16·31	59·75	16·57	59·67	16·83	62
63	60·85	16·31	60·78	16·57	60·71	16·83	60·63	17·10	63
64	61·82	16·56	61·75	16·83	61·67	17·10	61·60	17·37	64
65	62·79	16·82	62·71	17·10	62·64	17·37	62·56	17·64	65
66	63·75	17·08	63·68	17·36	63·60	17·64	63·52	17·92	66
67	64·72	17·34	64·64	17·62	64·56	17·90	64·48	18·19	67
68	65·68	17·60	65·61	17·89	65·53	18·17	65·45	18·46	68
69	66·65	17·86	66·57	18·15	66·49	18·44	66·41	18·73	69
70	67·61	18·12	67·54	18·41	67·45	18·71	67·37	19·00	70
71	68·58	18·38	68·50	18·68	68·42	18·97	68·33	19·27	71
72	69·55	18·63	69·46	18·94	69·38	19·24	69·30	19·54	72
73	70·51	18·89	70·43	19·20	70·35	19·51	70·26	19·82	73
74	71·48	19·15	71·39	19·46	71·31	19·78	71·22	20·09	74
75	72·44	19·41	72·36	19·73	72·27	20·04	72·18	20·36	75
76	73·41	19·67	73·32	19·99	73·24	20·31	73·15	20·63	76
77	74·38	19·93	74·29	20·25	74·20	20·58	74·11	20·90	77
78	75·34	20·19	75·25	20·52	75·16	20·84	75·07	21·17	78
79	76·31	20·45	76·22	20·78	76·13	21·11	76·03	21·44	79
80	77·27	20·71	77·18	21·04	77·09	21·38	77·00	21·72	80
81	78·24	20·96	78·15	21·31	78·05	21·65	77·96	21·99	81
82	79·21	21·22	79·11	21·57	79·02	21·91	78·92	22·26	82
83	80·17	21·48	80·08	21·83	79·98	22·18	79·88	22·53	83
84	81·14	21·74	81·04	22·09	80·94	22·45	80·85	22·80	84
85	82·10	22·00	82·01	22·36	81·91	22·72	81·81	23·07	85
86	83·07	22·26	82·97	22·62	82·87	22·98	82·77	23·34	86
87	84·04	22·52	83·94	22·88	83·84	23·25	83·73	23·62	87
88	85·00	22·78	84·90	23·15	84·80	23·52	84·70	23·89	88
89	85·97	23·03	85·87	23·41	85·76	23·78	85·66	24·16	89
90	86·93	23·29	86·83	23·67	86·73	24·05	86·62	24·43	90
91	87·90	23·55	87·80	23·94	87·69	24·32	87·58	24·70	91
92	88·87	23·81	88·76	24·20	88·65	24·59	88·55	24·97	92
93	89·83	24·07	89·73	24·46	89·62	24·85	89·51	25·24	93
94	90·80	24·33	90·69	24·72	90·58	25·12	90·47	25·52	94
95	91·76	24·59	91·65	24·99	91·54	25·39	91·43	25·79	95
96	92·73	24·85	92·62	25·25	92·51	25·65	92·40	26·06	96
97	93·69	25·11	93·58	25·51	93·47	25·92	93·36	26·33	97
98	94·66	25·36	94·55	25·78	94·44	26·19	94·32	26·60	98
99	95·63	25·62	95·51	26·04	95·40	26·46	95·28	26·87	99
100	96·59	25·88	96·48	26·30	96·36	26·72	96·25	27·14	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	75 Deg.		74¾ Deg.		74½ Deg.		74¼ Deg.		

Distance.	16 Deg.		16¼ Deg.		16½ Deg.		16¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·96	0·28	0·96	0·28	0·96	0·28	0·96	0·29	1
2	1·92	0·55	1·92	0·56	1·92	0·57	1·92	0·58	2
3	2·88	0·83	2·88	0·84	2·88	0·85	2·87	0·86	3
4	3·85	1·10	3·84	1·12	3·84	1·14	3·83	1·15	4
5	4·81	1·38	4·80	1·40	4·79	1·42	4·79	1·44	5
6	5·77	1·65	5·76	1·68	5·75	1·70	5·75	1·73	6
7	6·73	1·93	6·72	1·96	6·71	1·99	6·70	2·02	7
8	7·69	2·21	7·68	2·24	7·67	2·27	7·66	2·31	8
9	8·65	2·48	8·64	2·52	8·63	2·56	8·62	2·59	9
10	9·61	2·76	9·60	2·80	9·59	2·84	9·58	2·88	10
11	10·57	3·03	10·56	3·08	10·55	3·12	10·53	3·17	11
12	11·54	3·31	11·52	3·36	11·51	3·41	11·49	3·46	12
13	12·50	3·58	12·48	3·64	12·46	3·69	12·45	3·75	13
14	13·46	3·86	13·44	3·92	13·42	3·98	13·41	4·03	14
15	14·42	4·13	14·40	4·20	14·38	4·26	14·36	4·32	15
16	15·38	4·41	15·36	4·48	15·34	4·54	15·32	4·61	16
17	16·34	4·69	16·32	4·76	16·30	4·83	16·28	4·90	17
18	17·30	4·96	17·28	5·04	17·26	5·11	17·24	5·19	18
19	18·26	5·24	18·24	5·32	18·22	5·40	18·19	5·48	19
20	19·23	5·51	19·20	5·60	19·18	5·68	19·15	5·76	20
21	20·19	5·79	20·16	5·88	20·14	5·96	20·11	6·05	21
22	21·15	6·06	21·12	6·16	21·09	6·25	21·07	6·34	22
23	22·11	6·34	22·08	6·44	22·05	6·53	22·02	6·63	23
24	23·07	6·62	23·04	6·72	23·01	6·82	22·98	6·92	24
25	24·03	6·89	24·00	7·00	23·97	7·10	23·94	7·20	25
26	24·99	7·17	24·96	7·28	24·93	7·38	24·90	7·49	26
27	25·95	7·44	25·92	7·56	25·89	7·67	25·85	7·78	27
28	26·92	7·72	26·88	7·84	26·85	7·95	26·81	8·07	28
29	27·88	7·99	27·84	8·11	27·81	8·24	27·77	8·36	29
30	28·84	8·27	28·80	8·39	28·76	8·52	28·73	8·65	30
31	29·80	8·54	29·76	8·67	29·72	8·80	29·68	8·93	31
32	30·76	8·82	30·72	8·95	30·68	9·09	30·64	9·22	32
33	31·72	9·10	31·68	9·23	31·64	9·37	31·60	9·51	33
34	32·68	9·37	32·64	9·51	32·60	9·66	32·56	9·80	34
35	33·64	9·65	33·60	9·79	33·56	9·94	33·51	10·09	35
36	34·61	9·92	34·56	10·07	34·52	10·22	34·47	10·38	36
37	35·57	10·20	35·52	10·35	35·48	10·51	35·43	10·66	37
38	36·53	10·47	36·48	10·63	36·44	10·79	36·39	10·95	38
39	37·49	10·75	37·44	10·91	37·39	11·08	37·35	11·24	39
40	38·45	11·03	38·40	11·19	38·35	11·36	38·30	11·53	40
41	39·41	11·30	39·36	11·47	39·31	11·64	39·26	11·82	41
42	40·37	11·58	40·32	11·75	40·27	11·93	40·22	12·10	42
43	41·33	11·85	41·28	12·03	41·23	12·21	41·18	12·39	43
44	42·30	12·13	42·24	12·31	42·19	12·50	42·13	12·68	44
45	43·26	12·40	43·20	12·59	43·15	12·78	43·09	12·97	45
46	44·22	12·68	44·16	12·87	44·11	13·06	44·05	13·26	46
47	45·18	12·95	45·12	13·15	45·06	13·35	45·01	13·55	47
48	46·14	13·23	46·08	13·43	46·02	13·63	45·96	13·83	48
49	47·10	13·51	47·04	13·71	46·98	13·92	46·92	14·12	49
50	48·06	13·78	48·00	13·99	47·94	14·20	47·88	14·41	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	74 Deg.		73¾ Deg.		73½ Deg.		73¼ Deg.		

Distance.	16 Deg.		16¼ Deg.		16½ Deg.		16¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	49·02	14·06	48·96	14·27	48·90	14·48	48·84	14·70	51
52	49·99	14·33	49·92	14·55	49·86	14·77	49·79	14·99	52
53	50·95	14·61	50·88	14·83	50·82	15·05	50·75	15·27	53
54	51·91	14·88	51·84	15·11	51·78	15·34	51·71	15·56	54
55	52·87	15·16	52·80	15·39	52·74	15·62	52·67	15·85	55
56	53·83	15·44	53·76	15·67	53·69	15·90	53·62	16·14	56
57	54·79	15·71	54·72	15·95	54·65	16·19	54·58	16·43	57
58	55·75	15·99	55·68	16·23	55·61	16·47	55·54	16·72	58
59	56·71	16·26	56·64	16·51	56·57	16·76	56·50	17·00	59
60	57·68	16·54	57·60	16·79	57·53	17·04	57·45	17·29	60
61	58·64	16·81	58·56	17·07	58·49	17·32	58·41	17·58	61
62	59·60	17·09	59·52	17·35	59·45	17·61	59·37	17·87	62
63	60·56	17·37	60·48	17·63	60·41	17·89	60·33	18·16	63
64	61·52	17·64	61·44	17·91	61·36	18·18	61·28	18·44	64
65	62·48	17·92	62·40	18·19	62·32	18·46	62·24	18·73	65
66	63·44	18·19	63·36	18·47	63·28	18·74	63·20	19·02	66
67	64·40	18·47	64·32	18·75	64·24	19·03	64·16	19·31	67
68	65·37	18·74	65·28	19·03	65·20	19·31	65·11	19·60	68
69	66·33	19·02	66·24	19·31	66·16	19·60	66·07	19·89	69
70	67·29	19·29	67·20	19·59	67·12	19·88	67·03	20·17	70
71	68·25	19·57	68·16	19·87	68·08	20·17	67·99	20·46	71
72	69·21	19·85	69·12	20·15	69·03	20·45	68·95	20·75	72
73	70·17	20·12	70·08	20·43	69·99	20·73	69·90	21·04	73
74	71·13	20·40	71·04	20·71	70·95	21·02	70·86	21·33	74
75	72·09	20·67	72·00	20·99	71·91	21·30	71·82	21·61	75
76	73·06	20·95	72·96	21·27	72·87	21·59	72·78	21·90	76
77	74·02	21·22	73·92	21·55	73·83	21·87	73·73	22·19	77
78	74·98	21·50	74·88	21·83	74·79	22·15	74·69	22·48	78
79	75·94	21·78	75·84	22·11	75·75	22·44	75·65	22·77	79
80	76·90	22·05	76·80	22·39	76·71	22·72	76·61	23·06	80
81	77·86	22·33	77·76	22·67	77·66	23·01	77·56	23·34	81
82	78·82	22·60	78·72	22·95	78·62	23·29	78·52	23·63	82
83	79·78	22·88	79·68	23·23	79·58	23·57	79·48	23·92	83
84	80·75	23·15	80·64	23·51	80·54	23·86	80·44	24·21	84
85	81·71	23·43	81·60	23·79	81·50	24·14	81·39	24·50	85
86	82·67	23·70	82·56	24·07	82·46	24·43	82·35	24·78	86
87	83·63	23·98	83·52	24·35	83·42	24·71	83·31	25·07	87
88	84·59	24·26	84·48	24·62	84·38	24·99	84·27	25·36	88
89	85·55	24·53	85·44	24·90	85·33	25·28	85·22	25·65	89
90	86·51	24·81	86·40	25·18	86·29	25·56	86·18	25·94	90
91	87·47	25·08	87·36	25·46	87·25	25·85	87·14	26·23	91
92	88·44	25·36	88·32	25·74	88·21	26·13	88·10	26·51	92
93	89·40	25·63	89·28	26·02	89·17	26·41	89·05	26·80	93
94	90·36	25·91	90·24	26·30	90·13	26·70	90·01	27·09	94
95	91·32	26·19	91·20	26·58	91·09	26·98	90·97	27·38	95
96	92·28	26·46	92·16	26·86	92·05	27·27	91·93	27·67	96
97	93·24	26·74	93·12	27·14	93·01	27·55	92·88	27·95	97
98	94·20	27·01	94·08	27·42	93·96	27·83	93·84	28·24	98
99	95·16	27·29	95·04	27·70	94·92	28·12	94·80	28·53	99
100	96·13	27·56	96·00	27·98	95·88	28·40	95·76	28·82	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	74 Deg.		73¾ Deg.		73½ Deg.		73¼ Deg.		

Distance.	17 Deg.		17¼ Deg.		17½ Deg.		17¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·96	0·29	0·95	0·30	0·95	0·30	0·95	0·30	1
2	1·91	0·58	1·91	0·59	1·91	0·60	1·90	0·61	2
3	2·87	0·88	2·87	0·89	2·86	0·90	2·86	0·91	3
4	3·83	1·17	3·82	1·19	3·81	1·20	3·81	1·22	4
5	4·78	1·46	4·78	1·48	4·77	1·50	4·76	1·52	5
6	5·74	1·75	5·73	1·78	5·72	1·80	5·71	1·83	6
7	6·69	2·05	6·69	2·08	6·68	2·10	6·67	2·13	7
8	7·65	2·34	7·64	2·37	7·63	2·41	7·62	2·44	8
9	8·61	2·63	8·60	2·67	8·58	2·71	8·57	2·74	9
10	9·56	2·92	9·55	2·97	9·54	3·01	9·52	3·05	10
11	10·52	3·22	10·51	3·26	10·49	3·31	10·48	3·35	11
12	11·48	3·51	11·46	3·56	11·44	3·61	11·43	3·66	12
13	12·43	3·80	12·42	3·85	12·40	3·91	12·38	3·96	13
14	13·39	4·09	13·37	4.15	13·35	4·21	13·33	4·27	14
15	14·34	4·39	14·33	4·45	14·31	4·51	14·29	4·57	15
16	15·30	4·68	15·28	4·74	15·26	4·81	15·24	4·88	16
17	16·26	4·97	16·24	5·04	16·21	5·11	16·19	5·18	17
18	17·21	5·26	17·19	5·34	17·17	5·41	17·14	5·49	18
19	18·17	5·56	18·15	5·63	18·12	5·71	18·10	5·79	19
20	19·13	5·85	19·10	5·93	19·07	6·01	19·05	6·10	20
21	20·08	6·14	20·06	6·23	20·03	6·31	20·00	6·40	21
22	21·04	6·43	21·01	6·52	20·98	6·62	20·95	6·71	22
23	21·99	6·72	21·97	6·82	21·94	6·92	21·91	7·01	23
24	22·95	7·02	22·92	7·12	22·89	7·22	22·86	7·32	24
25	23·91	7·31	23·88	7·41	23·84	7·52	23·81	7·62	25
26	24·86	7·60	24·83	7·71	24·80	7·82	24·76	7·93	26
27	25·82	7·89	25·79	8·01	25·75	8·12	25·71	8·23	27
28	26·78	8·19	26·74	8·30	26·70	8·42	26·67	8·54	28
29	27·73	8·48	27·70	8·60	27·66	8·72	27·62	8·84	29
30	28·69	8·77	28·65	8·90	28·61	9·02	28·57	9·15	30
31	29·65	9·06	29·61	9·19	29·57	9·32	29·52	9·45	31
32	30·60	9·36	30·56	9·49	30·52	9·62	30·48	9·76	32
33	31·56	9·65	31·52	9·79	31·47	9·92	31·43	10·06	33
34	32·51	9·94	32·47	10·08	32·43	10·22	32·38	10·37	34
35	33·47	10·23	33·43	10·38	33·38	10·52	33·33	10·67	35
36	34·43	10·53	34·38	10·68	34·33	10·83	34·29	10·98	36
37	35·38	10·82	35·34	10·97	35·29	11·13	35·24	11·28	37
38	36·34	11·11	36·29	11·27	36·24	11·43	36·19	11·58	38
39	37·30	11·40	37·25	11·57	37·19	11·73	37·14	11·89	39
40	38·25	11·69	38·20	11·86	38·15	12·03	38·10	12·19	40
41	39·21	11·99	39·16	12·16	39·10	12·33	39·05	12·50	41
42	40·16	12·28	40·11	12·45	40·06	12·63	40·00	12·80	42
43	41·12	12·57	41·07	12·75	41·01	12·93	40·95	13·11	43
44	42·08	12·86	42·02	13·05	41·96	13·23	41·91	13·41	44
45	43·03	13·16	42·98	13·34	42·92	13·53	42·86	13·72	45
46	43·99	13·45	43·93	13·64	43·87	13·83	43·81	14·02	46
47	44·95	13·74	44·89	13·94	44·82	14·13	44·76	14·33	47
48	45·90	14·03	45·84	14·23	45·78	14·43	45·71	14·63	48
49	46·86	14·33	46·80	14·53	46·73	14·73	46·67	14·94	49
50	47·82	14·62	47·75	14·83	47·69	15·04	47·62	15·24	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	73 Deg.		72¾ Deg.		72½ Deg.		72¼ Deg.		

Distance.	17 Deg.		17¼ Deg.		17½ Deg.		17¾ Deg:		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	48·77	14·91	48·71	15·12	48·64	15·34	48·57	15·55	51
52	49·73	15·20	49·66	15·42	49·59	15·64	49·52	15·85	52
53	50·68	15·50	50·62	15·72	50·55	15·94	50·48	16·16	53
54	51·64	15·79	51·57	16·01	51·50	16·24	51·43	16·46	54
55	52·60	16·08	52·53	16·31	52·45	16·54	52·38	16·77	55
56	53·55	16·37	53·48	16·61	53·41	16·84	53·33	17·07	56
57	54·51	16·67	54·44	16·90	54·36	17·14	54·29	17·38	57
58	55·47	16·96	55·39	17·20	55·32	17·44	55·24	17·68	58
59	56·42	17·25	56·35	17·50	56·27	17·74	56·10	17·99	59
60	57·38	17·54	57·30	17·79	57·22	18·04	57·14	18·29	60
61	58·33	17·83	58·26	18·09	58·18	18·34	58·10	18·60	61
62	59·29	18·13	59·21	18·39	59·13	18·64	59·05	18·90	62
63	60·25	18·42	60·17	18·68	60·08	18·94	60·00	19·21	63
64	61·20	18·71	61·12	18·98	61·04	19·25	60·95	19·51	64
65	62·16	19·00	62·08	19·28	61·99	19·55	61·91	19·82	65
66	63·12	19·30	63·03	19·57	62·95	19·85	62·86	20·12	66
67	64·07	19·59	63·99	19·87	63·90	20·15	63·81	20·43	67
68	65·03	19·88	64·94	20·16	64·85	20·45	64·76	20·73	68
69	65·99	20·17	65·90	20·46	65·81	20·75	65·72	21·04	69
70	66·94	20·47	66·85	20·76	66·76	21·05	66·67	21·34	70
71	67·90	20·76	67·81	21·05	67·71	21·35	67·62	21·65	71
72	68·85	21·05	68·76	21·35	68·67	21·65	68·57	21·95	72
73	69·81	21·34	69·72	21·65	69·62	21·95	69·52	22·26	73
74	70·77	21·64	70·67	21·94	70·58	22·25	70·48	22·56	74
75	71·72	21·93	71·63	22·24	71·53	22·55	71·43	22·86	75
76	72·68	22·22	72·58	22·54	72·48	22·85	72·38	23·17	76
77	73·64	22·51	73·54	22·83	73·44	23·15	73·33	23·47	77
78	74·59	22·80	74·49	23·13	74·39	23·46	74·29	23·78	78
79	75·55	23·10	75·45	23·43	75·34	23·76	75·24	24·08	79
80	76·50	23·39	76·40	23·72	76·30	24·06	76·19	24·39	80
81	77·46	23·68	77·36	24·02	77·25	24·36	77·14	24·69	81
82	78·42	23·97	78·31	24·32	78·20	24·66	78·10	25·00	82
83	79·37	24·27	79·27	24·61	79·16	25·96	79·05	25·30	83
84	80·33	24·56	80·22	24·91	80·11	25·26	80·00	25·61	84
85	81·29	24·85	81·18	25·21	81·07	25·56	80·95	25·91	85
86	82·24	25·14	82·13	25·50	82·02	25·86	81·91	26·22	86
87	83·20	25·44	83·09	25·80	82·97	26·16	82·86	26·52	87
88	84·15	25·73	84·04	26·10	83·93	26·46	83·81	26·83	88
89	85·11	26·02	85·00	26·39	84·88	26·76	84·76	27·13	89
90	86·07	26·31	85·95	26·69	85·83	27·06	85·72	27·44	90
91	87·02	26·61	86·91	26·99	86·79	27·36	86·67	27·74	91
92	87·98	26·90	87·86	27·28	87·74	27·66	87·62	28·05	92
93	88·94	27·19	88·82	27·58	88·70	27·97	88·57	28·35	93
94	89·89	27·48	89·77	27·87	89·65	28·27	89·53	28·66	94
95	90·85	27·78	90·73	28·17	90·60	28·57	90·48	28·96	95
96	91·81	28·07	91·68	28·47	91·56	28·87	91·43	29·27	96
97	92·76	28·36	92·64	28·76	92·51	29·17	92·38	29·57	97
98	93·72	28·65	93·59	29·06	93·46	29·47	93·33	28·88	98
99	94·67	28·94	94·55	29·36	94·42	29·77	94·29	30·18	99
100	95·63	29·24	95·50	29·65	95·37	30·07	95·24	30·49	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	73 Deg.		72¾ Deg.		72½ Deg.		72¼ Deg.		

Distance.	18 Deg.		18¼ Deg.		18½ Deg.		18¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·95	0·31	0·95	0·31	0·95	0·32	0·95	0·32	1
2	1·90	0·62	1·90	0·63	1·90	0·63	1·89	0·64	2
3	2·85	0·93	2·85	0·94	2·84	0·95	2·84	0·96	3
4	3·80	1·24	3·80	1·25	3·79	1·27	3·79	1·29	4
5	4·76	1·55	4·75	1·57	4·74	1·59	4·73	1·61	5
6	5·71	1·85	5·70	1·88	5·69	1·90	5·68	1·93	6
7	6·66	2·16	6·65	2·19	6·64	2·22	6·63	2·25	7
8	7·61	2·47	7·60	2·51	7·59	2·54	7·58	2·57	8
9	8·56	2·78	8·55	2·82	8·53	2·86	8·52	2·89	9
10	9·51	3·09	9·50	3·13	9·48	3·17	9·47	3·21	10
11	10·46	3·40	10·45	3·44	10·43	3·49	10·42	3·54	11
12	11·41	3·71	11·40	3·76	11·38	3·81	11·36	3·86	12
13	12·36	4·02	12·35	4·07	12·33	4·12	12·31	4·18	13
14	13·31	4·33	13·30	4·38	13·28	4·44	13·26	4·50	14
15	14·27	4·64	14·25	4·70	14·22	4·76	14·20	4·82	15
16	15·22	4·94	15·20	5·01	15·17	5·08	15·15	5·14	16
17	16·17	5·25	16·14	5·32	16·12	5·39	16·10	5·46	17
18	17·12	5·56	17·09	5·64	17·07	5·71	17·04	5·79	18
19	18·07	5·87	18·04	5·95	18·02	6·03	17·99	6·11	19
20	19·02	6·18	18·99	6·26	18·97	6·35	18·94	6·43	20
21	19·97	6·49	19·94	6·58	19·91	6·66	19·89	6·75	21
22	20·92	6·80	20·89	6·89	20·86	6·98	20·83	7·07	22
23	21·87	7·11	21·84	7·20	21·81	7·30	21·78	7·39	23
24	22·83	7·42	22·79	7·52	22·76	7·62	22·73	7·71	24
25	23·78	7·73	23·74	7·83	23·71	7·93	23·67	8·04	25
26	24·73	8·03	24·69	8·14	24·66	8·25	24·62	8·36	26
27	25·68	8·34	25·64	8·46	25·60	8·57	25·57	8·68	27
28	26·63	8·65	26·59	8·77	26·55	8·88	26·51	9·00	28
29	27·58	8·96	27·54	9·08	27·50	9·20	27·46	9·32	29
30	28·53	9·27	28·49	9·39	28·45	9·52	28·41	9·64	30
31	29·48	9·58	29·44	9·71	29·40	9·84	29·35	9·96	31
32	30·43	9·89	30·39	10·02	30·35	10·15	30·30	10·29	32
33	31·38	10·20	31·34	10·33	31·29	10·47	31·25	10·61	33
34	32·34	10·51	32·29	10·65	32·24	10·79	32·20	10·93	34
35	33·29	10·82	33·24	10·96	33·19	11·11	33·14	11·25	35
36	34·24	11·12	34·19	11·27	34·14	11·42	34·09	11·57	36
37	35·19	11·43	35·14	11·59	35·09	11·74	35·04	11·89	37
38	36·14	11·74	36·09	11·90	36·04	12·06	35·98	12·21	38
39	37·09	12·05	37·04	12·21	36·98	12·37	36·93	12·54	39
40	38·04	12·36	37·99	12·53	37·93	12·69	37·88	12·86	40
41	38·99	12·67	38·94	12·84	38·88	13·01	38·82	13·18	41
42	39·94	12·98	39·89	13·15	39·83	13·33	39·77	13·50	42
43	40·90	13·29	40·84	13·47	40·78	13·64	40·72	13·82	43
44	41·85	13·60	41·79	13·78	41·73	13·96	41·66	14·14	44
45	42·80	13·91	42·74	14·09	42·67	14·28	42·61	14·46	45
46	43·75	14·21	43·69	14·41	43·62	14·60	43·56	14·79	46
47	44·70	14·52	44·64	14·72	44·57	14·91	44·51	15·11	47
48	45·65	14·83	45·59	15·03	45·52	15·23	45·45	15·43	48
49	46·60	15·14	46·54	15·35	46·47	15·55	46·40	15·75	49
50	47·55	15·45	47·48	15·66	47·42	15·87	47·35	16·07	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	72 Deg.		71¾ Deg.		71½ Deg.		71¼ Deg.		

Distance.	18 Deg.		18¼ Deg.		18½ Deg.		18¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	48·50	15·76	48·43	15·97	48·36	16·18	48·29	16·39	51
52	49·45	16·07	49·38	16·28	49·31	16·50	49·24	16·71	52
53	50·41	16·38	50·33	16·60	50·26	16·82	50·19	17·04	53
54	51·36	16·69	51·28	16·91	51·21	17·18	51·13	17·36	54
55	52·31	17·00	52·23	17·22	52·16	17·45	52·08	17·68	55
56	53·26	17·30	53·18	17·54	53·11	17·77	53·03	18·00	56
57	54·21	17·61	54·13	17·85	54·05	18·09	53·98	18·32	57
58	55·16	17·92	55·08	18·16	55·00	18·40	54·92	18·64	58
59	56·11	18·23	56·03	18·48	55·95	18·72	55·87	18·96	59
60	57·06	18·54	56·98	18·79	56·90	19·04	56·82	19·29	60
61	58·01	18·85	57·93	19·10	57·85	19·36	57·76	19·61	61
62	58·97	19·16	58·88	19·42	58·80	19·67	58·71	19·93	62
63	59·92	19·47	59·83	19·73	59·74	19·99	59·66	20·25	63
64	60·87	19·78	60·78	20·04	60·69	20·31	60·60	20·57	64
65	61·82	20·09	61·73	20·36	61·64	20·62	61·55	20·89	65
66	62·77	20·40	62·68	20·67	62·59	20·94	62·50	21·22	66
67	63·72	20·70	63·63	20·98	63·54	21·26	63·44	21·54	67
68	64·67	21·01	64·58	21·30	64·49	21·58	64·39	21·86	68
69	65·62	21·32	65·53	21·61	65·43	21·89	65·34	22·18	69
70	66·57	21·63	66·48	21·92	66·38	22·21	66·29	22·50	70
71	67·53	21·94	67·43	22·23	67·33	22·58	67·23	22·82	71
72	68·48	22·25	68·38	22·55	68·28	22·85	68·18	23·14	72
73	69·43	22·56	69·33	22·86	69·23	23·16	69·13	23·47	73
74	70·38	22·87	70·28	23·17	70·18	23·48	70·07	23·79	74
75	71·33	23·18	71·23	23·49	71·12	23·80	71·02	24·11	75
76	72·28	23·49	72·18	23·80	72·07	24·12	71·97	24·43	76
77	73·23	23·79	73·13	24·11	73·02	24·43	72·91	24·75	77
78	74·18	24·10	74·08	24·43	73·97	24·75	73·86	25·07	78
79	75·13	24·41	72·03	24·74	74·92	25·07	74·81	25·39	79
80	76·08	24·72	75·98	25·05	75·87	25·38	75·75	25·72	80
81	77·04	25·03	76·93	25·37	76·81	25·70	76·70	26·04	81
82	77·99	25·34	77·88	25·68	77·76	26·02	77·65	26·36	82
83	78·94	25·65	78·83	25·99	78·71	26·34	78·60	26·68	83
84	79·89	25·96	79·77	26·31	79·66	26·65	79·54	27·00	84
85	80·84	26·27	80·72	26·62	80·61	26·97	80·49	27·32	85
86	81·79	26·58	81·67	26·93	81·56	27·29	81·44	27·64	86
87	82·74	26·88	82·62	27·25	82·50	27·61	82·38	27·97	87
88	83·69	27·19	83·57	27·56	83·45	27·92	83·33	28·29	88
89	84·64	27·50	84·52	27·87	84·40	28·24	84·28	28·61	89
90	85·60	27·81	85·47	28·18	85·35	28·56	85·22	28·93	90
91	86·55	28·12	86·42	28·50	86·30	28·87	86·17	29·25	91
92	87·50	28·43	87·37	28·81	87·25	29·19	87·12	29·57	92
93	88·45	28·74	88·32	29·12	88·19	29·51	88·06	29·89	93
94	89·40	29·05	89·27	29·44	89·14	29·83	89·01	30·22	94
95	90·35	29·36	90·22	29·75	90·09	30·14	89·96	30·54	95
96	91·30	29·67	91·17	30·06	91·04	30·46	90·91	30·86	96
97	92·25	29·97	92·12	30·38	91·99	30·78	91·85	31·18	97
98	93·20	30·28	93·07	30·69	92·94	31·10	92·80	31·50	98
99	94·15	30·59	94·02	31·00	93·88	31·41	93·75	31·82	99
100	95·11	30·90	94·97	31·32	94·83	31·73	94·69	32·14	100
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
Distance.	72 Deg.		71¾ Deg.		71½ Deg.		71¼ Deg.		Distance.

Distance.	19 Deg.		19¼ Deg.		19½ Deg.		19¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·95	0·33	0·94	0·33	0·94	0·33	0·94	0·34	1
2	1·89	0·65	1·89	0·66	1·89	0·67	1·88	0·68	2
3	2·84	0·98	2·83	0·99	2·83	1·00	2·82	1·01	3
4	3·78	1·30	3·78	1·32	3·77	1·34	3·76	1·35	4
5	4·73	1·63	4·72	1·65	4·71	1·67	4·71	1·69	5
6	5·67	1·95	5·66	1·98	5·66	2·00	5·65	2·03	6
7	6·62	2·28	6·61	2·31	6·60	2·34	6·59	2·37	7
8	7·56	2·60	7·55	2·64	7·54	2·67	7·53	2·70	8
9	8·51	2·93	8·50	2·97	8·48	3·00	8·47	3·04	9
10	9·46	3·26	9·44	3·30	9·43	3·34	9·41	3·38	10
11	10·40	3·58	10·38	3·63	10·37	3·67	10·35	3·72	11
12	11·35	3·91	11·33	3·96	11·31	4·01	11·29	4·06	12
13	12·29	4·23	12·27	4·29	12·25	4·34	12·24	4·39	13
14	13·24	4·56	13·22	4·62	13·20	4·67	13·18	4·73	14
15	14·18	4·88	14·16	4·95	14·14	5·01	14·12	5·07	15
16	15·13	5·21	15·11	5·28	15·08	5·34	15·06	5·41	16
17	16·07	5·53	16·05	5·60	16·02	5·67	16·00	5·74	17
18	17·02	5·86	16·99	5·93	16·97	6·01	16·94	6·08	18
19	17·96	6·19	17·94	6·26	17·91	6·34	17·88	6·42	19
20	18·91	6·51	18·88	6·59	18·85	6·68	18·82	6·76	20
21	19·86	6·84	19·83	6·92	19·80	7·01	19·76	7·10	21
22	20·80	7·16	20·77	7·25	20·74	7·34	20·71	7·43	22
23	21·75	7·49	21·71	7·58	21·68	7·68	21·65	7·77	23
24	22·69	7·81	22·66	7·91	22·62	8·01	22·59	8·11	24
25	23·64	8·14	23·60	8·24	23·57	8·35	23·53	8·45	25
26	24·58	8·46	24·55	8·57	24·51	8·68	24·47	8·79	26
27	25·53	8·79	25·49	8·90	25·45	9·01	25·41	9·12	27
28	26·47	9·12	26·43	9·23	26·39	9·35	26·35	9·46	28
29	27·42	9·44	27·38	9·56	27·34	9·68	27·29	9·80	29
30	28·37	9·77	28·32	9·89	28·28	10·01	28·24	10·14	30
31	29·31	10·09	29·27	10·22	29·22	10·35	29·18	10·48	31
32	30·26	10·42	30·21	10·55	30·16	10·68	30·12	10·81	32
33	31·20	10·74	31·15	10·88	31·11	11·02	31·06	11·15	33
34	32·15	11·07	32·10	11·21	32·05	11·35	32·00	11·49	34
35	33·09	11·39	33·04	11·54	32·99	11·68	32·94	11·83	35
36	34·04	11·72	33·99	11·87	33·94	12·02	33·88	12·17	36
37	34·98	12·05	34·93	12·20	34·88	12·35	34·82	12·50	37
38	35·93	12·37	35·88	12·53	35·82	12·68	35·76	12·84	38
39	36·88	12·70	36·82	12·86	36·76	13·02	36·71	13·18	39
40	37·82	13·02	37·76	13·19	37·71	13·35	37·65	13·52	40
41	38·77	13·35	38·71	13·52	38·65	13·69	38·59	13·85	41
42	39·71	13·67	39·65	13·85	39·59	14·02	39·53	14·19	42
43	40·66	14·00	40·60	14·18	40·53	14·35	40·47	14·53	43
44	41·60	14·32	41·54	14·51	41·48	14·69	41·41	14·87	44
45	42·55	14·65	42·48	14·84	42·42	15·02	42·35	15·21	45
46	43·49	14·98	43·43	15·17	43·36	15·36	43·29	15·54	46
47	44·44	15·30	44·37	15·50	44·30	15·69	44·24	15·88	47
48	45·38	15·63	45·32	15·83	45·25	16·02	45·18	16·22	48
49	46·33	15·95	46·26	16·15	46·19	16·36	46·12	16·56	49
50	47·28	16·28	47·20	16·48	47·13	16·69	47·06	16·90	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	71 Deg.		70¾ Deg.		70½ Deg.		70¼ Deg.		

Distance.	19 Deg.		19¼ Deg.		19½ Deg.		19¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	48·22	16·60	48·15	16·81	48·07	17·02	48·00	17·23	51
52	49·17	16·93	49·09	17·14	49·02	17·36	48·94	17·57	52
53	50·11	17·26	50·04	17·47	49·96	17·69	49·88	17·91	53
54	51·06	17·58	50·98	17·80	50·90	18·03	50·82	18·25	54
55	52·00	17·91	51·92	18·13	51·85	18·36	51·76	18·59	55
56	52·95	18·23	52·87	18·46	52·79	18·69	52·71	18·92	56
57	53·89	18·56	53·81	18·79	53·73	19·03	53·65	19·26	57
58	54·84	18·88	54·76	19·12	54·67	19·36	54·59	19·60	58
59	55·79	19·21	55·70	19·45	55·62	19·69	55·53	19·94	59
60	56·73	19·53	56·65	19·78	56·56	20·03	56·47	20·27	60
61	57·68	19·86	57·59	20·11	57·50	20·36	57·41	20·61	61
62	58·62	20·19	58·53	20·44	58·44	20·70	58·35	20·95	62
63	59·57	20·51	59·48	20·77	59·39	21·03	59·29	21·29	63
64	60·51	20·84	60·42	21·10	60·33	21·36	60·24	21·63	64
65	61·46	21·16	61·37	21·43	61·27	21·70	61·18	21·96	65
66	62·40	21·49	62·31	21·76	62·21	22·03	62·12	22·30	66
67	63·35	21·81	63·25	22·09	63·16	22·37	63·06	22·64	67
68	64·30	22·14	64·20	22·42	64·10	22·70	64·00	22·98	68
69	65·24	22·46	65·14	22·75	65·04	23·03	64·94	23·32	69
70	66·19	22·79	66·09	23·08	65·98	23·37	65·88	23·65	70
71	67·13	23·12	67·03	23·41	66·93	23·70	66·82	23·99	71
72	68·08	23·44	67·97	23·74	67·87	24·03	67·76	24·33	72
73	69·02	23·77	68·92	24·07	68·81	24·37	68·71	24·67	73
74	69·97	24·09	69·86	24·40	69·76	24·70	69·65	25·01	74
75	70·91	24·42	70·81	24·73	70·70	25·04	70·59	25·34	75
76	71·86	24·74	71·75	25·06	71·64	25·37	71·53	25·68	76
77	72·80	25·07	72·69	25·39	72·58	25·70	72·47	26·02	77
78	73·75	25·39	73·64	25·72	73·53	26·04	73·41	26·36	78
79	74·70	25·72	74·58	26·05	74·47	26·37	74·35	26·70	79
80	75·64	26·05	75·53	26·38	75·41	26 70	75·29	27·03	80
81	76·59	26·37	76·47	26·70	76·35	27·04	76·24	27·37	81
82	77·53	26·70	77·42	27·03	77·30	27·37	77·18	27·71	82
83	78·48	27·02	78·36	27·36	78·24	27·71	78·12	28·05	83
84	79·42	27·35	79·30	27·69	79·18	28·04	79·06	28·39	84
85	80·37	27·67	80·25	28·02	80·12	28·37	80·00	28·72	85
86	81·31	28 00	81·19	28·35	81·07	28·71	80·94	29·06	86
87	82·26	28·32	82·14	28·68	82·01	29·04	81·88	29·40	87
88	83·21	28·65	83·08	29·01	82·95	29·37	82·82	29·74	88
89	84·15	28·98	84·02	29·34	83·90	29.71	83·76	30·07	89
90	85·10	29·30	84·97	29·67	84·84	30·04	84·71	30·41	90
91	86·04	29·63	85·91	30·00	85·78	30·38	85·65	30·75	91
92	86·99	29·95	86·86	30·33	86·72	30·71	86·59	31·09	92
93	87·93	30·28	87·80	30·66	87·67	31·04	87·53	31·43	93
94	88·88	30·60	88·74	30·99	88·61	31·38	88·47	31·76	94
95	89·82	30·93	89·69	31·32	89·55	31·71	89·41	32·10	95
96	90·77	31·25	90·63	31·65	90·49	32·05	90·35	32·44	96
97	91·72	31·58	91·58	31·98	91·44	32·38	91·29	32·78	97
98	92·66	31·91	92·52	32·31	92·38	32·71	92·24	33·12	98
99	93·61	32·23	93·46	32·64	93·32	33·05	93·18	33·45	99
100	94·55	32·56	94·41	32·97	94·26	33·38	94·12	33·79	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	71 Deg.		70¾ Deg.		70½ Deg.		70¼ Deg.		

Distance.	20 Deg.		20¼ Deg.		20½ Deg.		20¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·94	0·34	0·94	0·35	0·94	0·35	0·94	0·35	1
2	1·88	0·68	1·88	0·69	1·87	0·70	1·87	0·71	2
3	2·82	1·03	2·81	1·04	2·81	1·05	2·81	1·06	3
4	3·76	1·37	3·75	1·38	3·75	1·40	3·74	1·42	4
5	4·70	1·71	4·69	1·73	4·68	1·75	4·68	1·77	5
6	5·64	2·05	5·63	2·08	5·62	2·10	5·61	2·13	6
7	6·58	2·39	6·57	2·42	6·56	2·45	6·55	2·48	7
8	7·52	2·74	7·51	2·77	7·49	2·80	7·48	2·83	8
9	8·46	3·08	8·44	3·12	8·43	3·15	8·42	3·19	9
10	9·40	3·42	9·38	3·46	9·37	3·50	9·35	3·54	10
11	10·34	3·76	10·32	3·81	10·30	3·85	10·29	3·90	11
12	11·28	4·10	11·26	4·15	11·24	4·20	11·22	4·25	12
13	12·22	4·45	12·20	4·50	12·18	4·55	12·16	4·61	13
14	13·16	4·79	13·13	4·85	13·11	4·90	13·09	4·96	14
15	14·10	5·13	14·07	5·19	14·05	5·25	14·03	5·31	15
16	15·04	5·47	15·01	5·54	14·99	5·60	14·96	5·67	16
17	15·97	5·81	15·95	5·88	15·92	5·95	15·90	6·02	17
18	16·91	6·16	16·89	6·23	16·86	6·30	16·83	6·38	18
19	17·85	6·50	17·83	6·58	17·81	6·65	17·77	6·73	19
20	18·79	6·84	18·76	6·92	18·73	7·00	18·70	7·09	20
21	19·73	7·18	19·70	7·27	19·67	7·35	19·64	7·44	21
22	20·67	7·52	20·64	7·61	20·61	7·70	20·57	7·79	22
23	21·61	7.87	21·58	7·96	21·54	8·05	21·51	8·15	23
24	22·55	8·21	22·52	8·31	22·48	8·40	22·44	8·50	24
25	23·49	8·55	23·45	8·65	23·42	8·76	23·38	8·86	25
26	24·43	8·89	24·39	9·00	24·35	9·11	24·31	9·21	26
27	25·37	9·23	25·33	9·35	25·29	9·46	25·25	9·57	27
28	26·31	9·58	26·27	9·69	26·23	9·81	26·18	9·92	28
29	27·25	9·92	27·21	10·04	27·16	10·16	27·12	10·27	29
30	28·19	10·26	28·15	10·38	28·10	10·51	28·05	10·63	30
31	29·13	10·60	29·08	10·73	29·04	10·86	28·99	10·98	31
32	30·07	10·94	30·02	11·08	29·97	11·21	29·92	11·34	32
33	31·01	11·29	30·96	11·42	30·91	11·56	30·86	11·69	33
34	31·95	11·63	31·90	11·77	31·85	11·91	31·79	12·05	34
35	32·89	11·97	32·84	12·11	32·78	12·26	32·73	12·40	35
36	33·83	12·31	33·77	12·46	33·72	12·61	33·66	12·75	36
37	34·77	12·65	34·71	12·81	34·66	12·96	34·60	13·11	37
38	35·71	13·00	35·65	13·15	35·59	13·31	35·54	13·46	38
39	36·65	13·34	36·59	13·50	36·53	13·66	36·47	13·82	39
40	37·59	13·68	37·53	13·84	37·47	14·01	37·41	14·17	40
41	38·53	14·02	38·47	14·19	38·40	14·36	38·34	14·53	41
42	39·47	14·36	39·40	14·54	39·34	14·71	39·28	14·88	42
43	40·41	14·71	40·34	14·88	40·28	15·06	40·21	15·23	43
44	41·35	15·05	41·28	15·23	41·21	15·41	41·15	15·59	44
45	42·29	15·39	42·22	15·58	42·15	15·76	42·08	15·94	45
46	43·23	15·73	43·16	15·92	43·09	16·11	43·02	16·30	46
47	44·17	16·07	44·09	16·27	44·02	16·46	43·95	16·65	47
48	45·11	16·42	45·03	16·61	44·96	16·81	44·89	17·01	48
49	46·04	16·76	45·97	16·96	45·90	17·16	45·82	17·36	49
50	46·98	17·10	46·91	17·31	46·83	17·51	46·76	17·71	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	70 Deg.		69¾ Deg.		69½ Deg.		69¼ Deg.		

Distance.	20 Deg. Lat.	20 Deg. Dep.	20¼ Deg. Lat.	20¼ Deg. Dep.	20½ Deg. Lat.	20½ Deg. Dep.	20¾ Deg. Lat.	20¾ Deg. Dep.	Distance.
51	47·92	17·44	47·85	17·65	47·77	17·86	47·69	18·07	51
52	48·86	17·79	48·79	18·00	48·71	18·21	48·63	18·42	52
53	49·80	18·13	49·72	18·34	49·64	18·56	49·56	18·78	53
54	50·74	18·47	50·66	18·69	50·58	18·91	50·50	19·13	54
55	51·68	18·81	51·60	19·04	51·52	19·26	51·43	19·49	55
56	52·62	19·15	52·54	19·38	52·45	19·61	52·37	19·84	56
57	53·56	19·50	53·48	19·73	53·39	19·96	53·30	20·19	57
58	54·50	19·84	54·42	20·07	54·33	20·31	54·24	20·55	58
59	55·44	20·18	55·35	20·42	55·26	20·66	55·17	20·90	59
60	56·38	20·52	56·29	20·77	56·20	21·01	56·11	21·26	60
61	57·32	20·86	57·23	21·11	57·14	21·36	57·04	21·61	61
62	58·26	21·21	58·17	21·46	58·07	21·71	57·98	21·97	62
63	59·20	21·55	59·11	21·81	59·01	22·06	58·91	22·32	63
64	60·14	21·89	60·04	22·15	59·95	22·41	59·85	22·67	64
65	61·08	22·23	60·98	22·50	60·88	22·76	60·78	23·03	65
66	62·02	22·57	61·92	22·84	61·82	23·11	61·72	23·38	66
67	62·96	22·92	62·86	23·19	62·76	23·46	62·65	23·74	67
68	63·90	23·26	63·80	23·54	63·69	23·81	63·59	24·09	68
69	64·84	23·60	64·74	23·88	64·63	24·16	64·52	24·45	69
70	65·78	23·94	65·67	24·23	65·57	24·51	65·46	24·80	70
71	66·72	24·28	66·61	24·57	66·50	24·86	66·39	25·15	71
72	67·66	24·63	67·55	24·92	67·44	25·21	67·33	25·51	72
73	68·60	24·97	68·49	25·27	68·38	25·57	68·26	25·86	73
74	69·54	25·31	69·43	25·61	69·31	25·92	69·20	26·22	74
75	70·48	25·65	70·36	25·96	70·25	26·27	70·14	26·57	75
76	71·42	25·99	71·30	26·30	71·19	26·62	71·07	26·93	76
77	72·36	26·34	72·24	26·65	72·12	26·97	72·01	27·28	77
78	73·30	26·68	73·18	27·00	73·06	27·32	72·94	27·63	78
79	74·24	27·02	74·12	27·34	74·00	27·67	73·88	27·99	79
80	75·18	27·36	75·06	27·69	74·93	28·02	74·81	28·34	80
81	76·12	27·70	75·99	28·04	75·87	28·37	75·75	28·70	81
82	77·05	28·05	76·93	28·38	76·81	28·72	76·68	29·05	82
83	77·99	28·39	77·87	28·73	77·74	29·07	77·62	29·41	83
84	78·93	28·73	78·81	29.07	78·68	29·42	78·55	29·76	84
85	79·87	29·07	79·75	29·42	79·62	29·77	79·49	30·11	85
86	80·81	29·41	80·68	29·77	80·55	30·12	80·42	30·47	86
87	81·75	29·76	81·62	30·11	81·49	30·47	81·36	30·82	87
88	82·69	30·10	82·56	30·46	82·43	30·82	82·29	31·18	88
89	83·63	30·44	83·50	30·80	83·36	31·17	83·23	31·53	89
90	84·57	30·78	84·44	31·15	84·30	31·52	84·16	31·89	90
91	85·51	31·12	85·38	31·50	85·24	31·87	85·10	32·24	91
92	86·45	31·47	86·31	31·84	86·17	32·22	86·03	32·59	92
93	87·39	31·81	87·25	32·19	87·11	32·57	86·97	32·95	93
94	88·33	32·15	88·19	32·54	88·05	32·92	87·90	33·30	94
95	89·27	32·49	89·13	32·88	88·98	33·27	88·84	33·66	95
96	90·21	32·83	90·07	33·23	89·92	33·62	89·77	34·01	96
97	91·15	33·18	91·00	33·57	90·86	33·97	90·71	34·37	97
98	92·09	33·52	91·94	33·92	91·79	34·32	91·64	34·72	98
99	93·03	33·86	92·88	34·27	92·73	34·67	92·58	35·07	99
100	93·97	34·20	93·82	34·61	93·67	35·02	93·51	35·43	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	70 Deg.		69¾ Deg.		69½ Deg.		69¼ Deg.		

Distance.	21 Deg.		21¼ Deg.		21½ Deg.		21¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·93	0·36	0·93	0·36	0·93	0·37	0·93	0·37	1
2	1·87	0·72	1·86	0·72	1·86	0·73	1·86	0·74	2
3	2·80	1·08	2·80	1·09	2·79	1·10	2·79	1·11	3
4	3·73	1·43	3·73	1·45	3·72	1·47	3·72	1·48	4
5	4·67	1·79	4·66	1·81	4·65	1·83	4·64	1·85	5
6	5·60	2·15	5·59	2·17	5·58	2·20	5·57	2·22	6
7	6·54	2·51	6·52	2·54	6·51	2·57	6·50	2·59	7
8	7·47	2·87	7·46	2·90	7·44	2·93	7·43	2·96	8
9	8·40	3·23	8·39	3·26	8·37	3·30	8·36	3·34	9
10	9·34	3·58	9·32	3·62	9·30	3·67	9·29	3·71	10
11	10·27	3·94	10·25	3·99	10·23	4·03	10·22	4·08	11
12	11·20	4·30	11·18	4·35	11·17	4·40	11·15	4·45	12
13	12·14	4·66	12·12	4·71	12·10	4·76	12·07	4·82	13
14	13·07	5·02	13·05	5·07	13·03	5·13	13·00	5·19	14
15	14·00	5·38	13·98	5·44	13·96	5·50	13·93	5·56	15
16	14·94	5·73	14·91	5·80	14·89	5·86	14·86	5·93	16
17	15·87	6·09	15·84	6·16	15·82	6·23	15·79	6·30	17
18	16·80	6·45	16·78	6·52	16·75	6·60	16·72	6·67	18
19	17·74	6·81	17·71	6·89	17·68	6·96	17·65	7·04	19
20	18·67	7·17	18·64	7·25	18·61	7·33	18·58	7·41	20
21	19·61	7·53	19·57	7·61	19·54	7·70	19·50	7·78	21
22	20·54	7·88	20·50	7·97	20·47	8·06	20·43	8·15	22
23	21·47	8·24	21·44	8·34	21·40	8·43	21·36	8·52	23
24	22·41	8·60	22·37	8·70	22·33	8·80	22·29	8·89	24
25	23·34	8·96	23·30	9·06	23·26	9·16	23·22	9·26	25
26	24·27	9·32	24·23	9·42	24·19	9·53	24·15	9·63	26
27	25·21	9·68	25·16	9·79	25·12	9·90	25·08	10·01	27
28	26·14	10·03	26·10	10·15	26·05	10·26	26·01	10·38	28
29	27·07	10·39	27·03	10·51	26·98	10·63	26·94	10·75	29
30	28·01	10·75	27·96	10·87	27·91	11·00	27·86	11·12	30
31	28·94	11·11	28·89	11·24	28·84	11·36	28·79	11·49	31
32	29·87	11·47	29·82	11·60	29·77	11·73	29·72	11·86	32
33	30·81	11·83	30·76	11·96	30·70	12·09	30·65	12·23	33
34	31·74	12·18	31·69	12·32	31·63	12·46	31·58	12·60	34
35	32·68	12·54	32·62	12·69	32·56	12·83	32·51	12·97	35
36	33·61	12·90	33·55	13·05	33·50	13·19	33·44	13·34	36
37	34·54	13·26	34·48	13·41	34·43	13·56	34·37	13·71	37
38	35·48	13·62	35·42	13·77	35·36	13·93	35·29	14·08	38
39	36·41	13·98	36·35	14·14	36·29	14·29	36·22	14·45	39
40	37·34	14·33	37·28	14·50	37·22	14·66	37·15	14·82	40
41	38·28	14·69	38·21	14·86	38·15	15·03	38·08	15·19	41
42	39·21	15·05	39·14	15·22	39·08	15·39	39·01	15·56	42
43	40·14	15·41	40·08	15·58	40·01	15·76	39·94	15·93	43
44	41·08	15·77	41·01	15·95	40·94	16·13	40·87	16·30	44
45	42·01	16·13	41·94	16·31	41·87	16·49	41·80	16·68	45
46	42·94	16·48	42·87	16·67	42·80	16·86	42·73	17·05	46
47	43·88	16·84	43·80	17·03	43·73	17·23	43·65	17·42	47
48	44·81	17·20	44·74	17·40	44·66	17·59	44·58	17·79	48
49	45·75	17·56	45·67	17·76	45·59	17·96	45·51	18·16	49
50	46·68	17·92	46·60	18·12	46·52	18·33	46·44	18·53	50
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
Distance.	69 Deg.		68¾ Deg.		68½ Deg.		68¼ Deg.		Distance.

Distance.	21 Deg. Lat.	21 Deg. Dep.	21¼ Deg. Lat.	21¼ Deg. Dep.	21½ Deg. Lat.	21½ Deg. Dep.	21¾ Deg. Lat.	21¾ Deg. Dep.	Distance.
51	47·61	18·28	47·53	18·48	47·45	18·69	47·37	18·90	51
52	48·55	18·64	48·46	18·85	48·38	19·06	48·30	19·27	52
53	49·48	18·99	49·40	19·21	49·31	19·42	49·23	19·64	53
54	50·41	19·35	50·33	19·57	50·24	19·79	50·16	20·01	54
55	51·35	19·71	51·26	19·93	51·17	20·16	51·08	20·38	55
56	52·28	20·07	52·19	20·30	52·10	20·52	52·01	20·75	56
57	53·21	20·43	53·12	20·66	53·03	20·89	52·94	21·12	57
58	54·15	20·79	54·06	21·02	53·96	21·26	53·87	21·49	58
59	55·08	21·14	54·99	21·38	54·89	21·62	54·80	21·86	59
60	56·01	21·50	55·92	21·75	55·83	21·99	55·73	22·23	60
61	56·95	21·86	56·85	22·11	56·76	22·36	56·66	22·60	61
62	57·88	22·22	57·78	22·47	57·69	22·72	57·59	22·97	62
63	58·82	22·58	58·72	22·83	58·62	23·09	58·52	23·35	63
64	59·75	22·94	59·65	23·20	59·55	23·46	59·44	23·72	64
65	60·68	23·29	60·58	23·56	60·48	23·82	60·37	24·09	65
66	61·62	23·65	61·51	23·92	61·41	24·19	61·30	24·46	66
67	62·55	24·01	62·44	24·28	62·34	24·56	62·23	24·83	67
68	63·48	24·37	63·38	24·65	63·27	24·92	63·16	25·20	68
69	64·42	24·73	64·31	25·01	64·20	25·29	64·09	25·57	69
70	65·35	25·09	65·24	25·37	65·13	25·66	65·02	25·94	70
71	66·28	25·44	66·17	25·73	66·06	26·02	65·95	26·31	71
72	67·22	25·80	67·10	26·10	66·99	26·39	66·87	26·68	72
73	68·15	26·16	68·04	26·46	67·92	26·75	67·80	27·05	73
74	69·08	26·52	68·97	26·82	68·85	27·12	68·73	27·42	74
75	70·02	26·88	69·90	27·18	69·78	27·49	69·66	27·79	75
76	70·95	27·24	70·83	27·55	70·71	27·85	70·59	28·16	76
77	71·89	27·59	71·76	27·91	71·64	28·22	71·52	28·53	77
78	72·82	27·95	72·70	28·27	72·57	28·59	72·45	28·90	78
79	73·75	28·31	73·63	28·63	73·50	28·95	73·38	29·27	79
80	74·69	28·67	74·56	29·00	74·43	29·32	74·30	29·64	80
81	75·62	29·03	75·49	29·36	75·36	29·69	75·23	30·02	81
82	76·55	29·39	76·42	29·72	76·29	30·05	76·16	30·39	82
83	77·49	29·74	77·36	30·08	77·22	30·42	77·09	30·76	83
84	78·42	30·10	78·29	30·44	78·16	30·79	78·02	31·13	84
85	79·35	30·46	79·22	30·81	79·09	31·15	78·95	31·50	85
86	80·29	30·82	80·15	31·17	80·02	31·52	79·88	31·87	86
87	81·22	31·18	81·08	31·53	80·95	31·89	80·81	32·24	87
88	82·16	31·54	82·02	31·89	81·88	32·25	81·74	32·61	88
89	83·09	31·89	82·95	32·26	82·81	32·62	82·66	32·98	89
90	84·02	32·25	83·88	32·62	83·74	32·99	83·59	33·35	90
91	84·96	32·61	84·81	32·98	84·67	33·35	84·52	33·72	91
92	85·89	32·97	85·74	33·34	85·60	33·72	85·45	34·09	92
93	86·82	33·33	86·68	33·71	86·53	34·08	86·38	34·46	93
94	87·76	33·69	87·61	34·07	87·46	34·45	87·31	34·83	94
95	88·69	34·04	88·54	34·43	88·39	34·82	88·24	35·20	95
96	89·62	34·40	89·47	34·79	89·32	35·18	89·17	35·57	96
97	90·56	34·76	90·40	35·16	90·25	35·55	90·09	35·94	97
98	91·49	35·12	91·34	35·52	91·18	35·92	91·02	36·31	98
99	92·42	35·48	92·27	35·88	92·11	36·28	91·95	36·69	99
100	93·36	35·84	93·20	36·24	93·04	36·65	92·88	37·06	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	69 Deg.		68¾ Deg.		68½ Deg.		68¼ Deg.		

Distance.	22 Deg.		22¼ Deg.		22½ Deg.		22¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·93	0·37	0·93	0·38	0·92	0·38	0·92	0·39	1
2	1·85	0·75	1·85	0·76	1·85	0·77	1·84	0·77	2
3	2·78	1·12	2·78	1·14	2·77	1·15	2·77	1·16	3
4	3·71	1·50	3·70	1·51	3·70	1·53	3·69	1·55	4
5	4·64	1·87	4·63	1·89	4·62	1·91	4·61	1·93	5
6	5·56	2·25	5·55	2·27	5·54	2·30	5·53	2·32	6
7	6·49	2·62	6·48	2·65	6·47	2·68	6·46	2·71	7
8	7·42	3·00	7·40	3·03	7·39	3·06	7·38	3·09	8
9	8·34	3·37	8·33	3·41	8·31	3·44	8·30	3·48	9
10	9·27	3·75	9·26	3·79	9·24	3·83	9·22	3·87	10
11	10·20	4·12	10·18	4·17	10·16	4·21	10·14	4·25	11
12	11·13	4·50	11·11	4·54	11·09	4·59	11·07	4·64	12
13	12·05	4·87	12·03	4·92	12·01	4·97	11·99	5·03	13
14	12·98	5·24	12·96	5·30	12·93	5·36	12·91	5·41	14
15	13·91	5·62	13·88	5·68	13·86	5·74	13·83	5·80	15
16	14·83	5·99	14·81	6·06	14·78	6·12	14·76	6·19	16
17	15·76	6·37	15·73	6·44	15·71	6·51	15·68	6·57	17
18	16·69	6·74	16·66	6·82	16·63	6·89	16·60	6·96	18
19	17·62	7·12	17·59	7·19	17·55	7·27	17·52	7·35	19
20	18·54	7·49	18·51	7·57	18·48	7·65	18·44	7·73	20
21	19·47	7·87	19·44	7·95	19·40	8·04	19·37	8·12	21
22	20·40	8·24	20·36	8·33	20·33	8·42	20·29	8·51	22
23	21·33	8·62	21·29	8·71	21·25	8·80	21·21	8·89	23
24	22·25	8·99	22·21	9·09	22·17	9·18	22·13	9·28	24
25	23·18	9·37	23·14	9·47	23·10	9·57	23·05	9·67	25
26	24·11	9·74	24·06	9·84	24·02	9·95	23·98	10·05	26
27	25·03	10·11	24·99	10·22	24·94	10·33	24·90	10·44	27
28	25·96	10·49	25·92	10·60	25·87	10·72	25·82	10·83	28
29	26.89	10·86	26·84	10·98	26·79	11·10	26·74	11·21	29
30	27·82	11·24	27·77	11·36	27·72	11·48	27·67	11·60	30
31	28·74	11·61	28·69	11·74	28·64	11·86	28·59	11·99	31
32	29·67	11·99	29·62	12·12	29·56	12·25	29·51	12·37	32
33	30·60	12·36	30·54	12·50	30·49	12·63	30·43	12·76	33
34	31·52	12·74	31·47	12·87	31·41	13·01	31·35	13·15	34
35	32·45	13·11	32·39	13·25	32·34	13·39	32·28	13·53	35
36	33·38	13·49	33·32	13·63	33·26	13·78	33·20	13·92	36
37	34·31	13·86	34·24	14·01	34·18	14·16	34·12	14·31	37
38	35·23	14·24	35·17	14·39	35·11	14·54	35·04	14·70	38
39	36·16	14·61	36·10	14·77	36·03	14·92	35·97	15·08	39
40	37·09	14·98	37·02	15·15	36·96	15·31	36·89	15·47	40
41	38·01	15·36	37·95	15·52	37·88	15·69	37·81	15·86	41
42	38·94	15·73	38·87	15·90	38·80	16·07	38·73	16·24	42
43	39·87	16·11	39·80	16·28	39·73	16·46	39·65	16·63	43
44	40·80	16·48	40·72	16·66	40·65	16·84	40·58	17·02	44
45	41·72	16·86	41·65	17·04	41·57	17·22	41·50	17·40	45
46	42·65	17·23	42·57	17·42	42·50	17·60	42·42	17·79	46
47	43·58	17·61	43·50	17·80	43·42	17·99	43·34	18·18	47
48	44·50	17·98	44·43	18·18	44·35	18·37	44·27	18·56	48
49	45·43	18·36	45·35	18·55	45·27	18·75	45·19	18·95	49
50	46·36	18·73	46·28	18·93	46·19	19·13	46·11	19·34	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	68 Deg.		67¾ Deg.		67½ Deg.		67¼ Deg.		

Distance.	22 Deg.		22¼ Deg.		22½ Deg.		22¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	47·29	19·10	47·20	19·31	47·12	19·52	47·03	19.72	51
52	48·21	19·48	48·13	19·69	48·04	19·90	47·95	20·11	52
53	49·14	19·85	49·05	20·07	48·97	20·28	48·88	20·50	53
54	50·07	20·23	49·98	20·45	49·89	20·66	49·80	20·88	54
55	51·00	20·60	50·90	20·83	50·81	21·05	50·72	21·27	55
56	51·92	20·98	51·83	21·20	51·74	21·43	51·64	21·66	56
57	52·85	21·35	52·76	21·58	52·66	21·81	52·57	22·04	57
58	53·78	21·73	53·68	21·96	53·59	22·20	53·49	22·43	58
59	54·70	22·10	54·61	22·34	54·51	22·58	54·41	22·82	59
60	55·63	22·48	55·53	22·72	55·43	22·96	55·33	23·20	60
61	56·56	22·85	56·47	23·10	56·36	23·34	56·25	23·59	61
62	57·49	23·23	57·38	23·48	57·28	23·73	57·18	23·98	62
63	58·41	23·60	58·31	23·85	58·20	24·11	58·10	24·36	63
64	59·34	23·97	59·23	24·23	59·13	24·49	59·02	24·75	64
65	60·27	24·35	60·16	24·61	60·05	24·87	59·94	25·14	65
66	61·19	24·72	61·09	24·99	60·98	25·26	60·87	25·52	66
67	62·12	25·10	62·01	25·37	61·90	25·64	61·79	25·91	67
68	63·05	25·47	62·94	25·75	62·82	26·02	62·71	26·30	68
69	63·98	25·85	63·86	26·13	63·75	26·41	63·63	26·68	69
70	64·90	26·22	64·79	26·51	64·67	26·79	64·55	27·07	70
71	65·83	26·60	65·71	26·88	65·60	27·17	65·48	27·46	71
72	66·76	26·97	66·64	27·26	66·52	27·55	66·40	27·84	72
73	67·68	27·35	67·56	27·64	67·44	27·94	67·32	28·23	73
74	68·61	27·72	68·49	28·02	68·37	28·32	68·24	28·62	74
75	69·54	28·10	69·42	28·40	69·29	28·70	69·17	29·00	75
76	70·47	28·47	70·34	28·78	70·21	29·08	70·09	29·39	76
77	71·39	28·84	71·27	29·16	71·14	29·47	71·01	29·78	77
78	72·32	29·22	72·19	29·53	72·06	29·85	71·93	30·16	78
79	73·25	29·59	73·12	29·91	72·99	30·23	72·85	30·55	79
80	74·17	29·97	74·04	30·29	73·91	30·61	73·78	30·94	80
81	75·10	30·34	74·97	30·67	74·83	31·00	74·70	31·32	81
82	76·03	30·72	75·89	31·05	75·76	31·38	75·62	31·71	82
83	76·96	31·09	76·82	31·43	76·68	31·76	76·54	32·10	83
84	77·88	31·47	77·75	31·81	77·61	32·15	77·46	32·48	84
85	78·81	31·84	78·67	32·19	78·53	32·53	78·39	32·87	85
86	79·74	32·22	79·60	32·56	79·45	32·91	79·31	33·26	86
87	80·66	32·59	80·52	32·94	80·38	33·29	80·23	33·64	87
88	81·59	32·97	81·45	33·32	81·30	33·68	81·15	34·03	88
89	82·52	33·34	82·37	33·70	82·23	34·06	82·08	34·42	89
90	83·45	33·71	83·30	34·08	83·15	34·44	83·00	34·80	90
91	84·37	34·09	84·22	34·46	84·07	34·82	83·92	35·19	91
92	85·30	34·46	85·15	34·84	85·00	35·21	84·84	35·58	92
93	86·23	34·84	86·08	35·21	85·92	35·59	85·76	35·96	93
94	87·16	35·21	87·00	35·59	86·84	35·97	86·69	36·35	94
95	88·08	35·59	87·93	35·97	87·77	36·35	87·61	36·74	95
96	89·01	35·96	88·85	36·35	88·69	36·74	88·53	37·12	96
97	89·94	36·34	89·78	36·73	89·62	37·12	89·45	37·51	97
98	90·86	36·71	90·70	37·11	90·54	37·50	90·38	37·90	98
99	91·97	37·09	91·63	37·49	91·46	37·89	91·30	38·28	99
100	92·72	37·46	92·55	37·86	92·39	38·27	92·22	38·67	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	68 Deg.		67¾ Deg.		67½ Deg.		67¼ Deg.		

Distance.	23 Deg.		23¼ Deg.		23½ Deg.		23¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·92	0·39	0·92	0·39	0·92	0·40	0·92	0·40	1
2	1·84	0·78	1·84	0·79	1·83	0·80	1·83	0·81	2
3	2·76	1·17	2·76	1·18	2·75	1·20	2·75	1·21	3
4	3·68	1·56	3·68	1·58	3·67	1·59	3·66	1·61	4
5	4·60	1·95	4·59	1·97	4·59	1·99	4·58	2·01	5
6	5·52	2·34	5·51	2·37	5·50	2·39	5·49	2·42	6
7	6·44	2·74	6·43	2·76	6·42	2·79	6·41	2·82	7
8	7·36	3·13	7·35	3·16	7·34	3·19	7·32	3·22	8
9	8·28	3·52	8·27	3·55	8·25	3·59	8·24	3·62	9
10	9·20	3·91	9·19	3·95	9·17	3·99	9·15	4·03	10
11	10·13	4·30	10·11	4·34	10·09	4·39	10·07	4·43	11
12	11·05	4·69	11·03	4·74	11·00	4·78	10·98	4·83	12
13	11·97	5·08	11·94	5·13	11·92	5·18	11·90	5·24	13
14	12·89	5·47	12·86	5·53	12·84	5·58	12·81	5·64	14
15	13·81	5·86	13·78	5·92	13·76	5·98	13·73	6·04	15
16	14·73	6·25	14·70	6·32	14·67	6·38	14·64	6·44	16
17	15·65	6·64	15·62	6·71	15·59	6·78	15·56	6·85	17
18	16·57	7·03	16·54	7·11	16·51	7·18	16·48	7·25	18
19	17·49	7·42	17·46	7·50	17·42	7·58	17·39	7·65	19
20	18·41	7·81	18·38	7·89	18·34	7·97	18·31	8·05	20
21	19·33	8·21	19·29	8·29	19·26	8·37	19·22	8·46	21
22	20·25	8·60	20·21	8·68	20·18	8·77	20·14	8·86	22
23	21·17	8·99	21·13	9·08	21·09	9·17	21·05	9·26	23
24	22·09	9·38	22·05	9·47	22·01	9·57	21·97	9·67	24
25	23·01	9·77	22·97	9·87	22·93	9·97	22·88	10·07	25
26	23·93	10·16	23·89	10·26	23·84	10·37	23·80	10·47	26
27	24·85	10·55	24·81	10·66	24·76	10·77	24·71	10·87	27
28	25·77	10·94	25·73	11·05	25·68	11·16	25·63	11·28	28
29	26·69	11·33	26 64	11·45	26·59	11·56	26·54	11·68	29
30	27·62	11·72	27·56	11·84	27·51	11·96	27·46	12·08	30
31	28·54	12·11	28·48	12·24	28·43	12·36	28·37	12·49	31
32	29·46	12·50	29·40	12·63	29·35	12·76	29·29	12·89	32
33	30·38	12·89	30·32	13·03	30·26	13·16	30·21	13·29	33
34	31·30	13·28	31·24	13·42	31·18	13·56	31·12	13·69	34
35	32·22	13·68	32·16	13·82	32·10	13·96	32·04	14·10	35
36	33·14	14·07	33·08	14·21	33·01	14·35	32·95	14·50	36
37	34·06	14·46	34·00	14·61	33·93	14·75	33·87	14·90	37
38	34·98	14·85	34·91	15·00	34·85	15·15	34·87	15·30	38
39	35·90	15·24	35·83	15·39	35·77	15·55	35·70	15·71	39
40	36·82	15·63	36·75	15·79	36·68	15·95	36·61	16·11	40
41	37·74	16·02	37·67	16·18	37·60	16·35	37·53	16·51	41
42	38·66	16·41	38·59	16·58	38 52	16·75	38·44	16·92	42
43	39·58	16·80	39·51	16·97	39·43	17·15	39·36	17·32	43
44	40·50	17·19	40·43	17·37	40·35	17·54	40·27	17·72	44
45	41·42	17·58	41·35	17·76	41·27	17·94	41·19	18·12	45
46	42·34	17·97	42·26	18·16	42·18	18·34	42·10	18·53	46
47	43·26	18·36	43·18	18·55	43·10	18·74	43·02	18·93	47
48	44·18	18·76	44·19	18·95	44·02	19·14	43·93	19·33	48
49	45·10	19·15	45·02	19·34	44·94	19·54	44·85	19·73	49
50	46·03	19·54	45·94	19·74	45·85	19·94	45·77	20·14	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	67 Deg.		66¾ Deg.		66½ Deg.		66¼ Deg.		

Distance.	23 Deg.		23¼ Deg.		23½ Deg.		23¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	46·95	19·93	46·86	20·13	46·77	20·34	46·68	20·54	51
52	47·87	20·32	47·78	20·53	47·69	20·73	47·60	20·94	52
53	48·79	20·71	48·70	20·92	48·60	21·13	48·51	21·35	53
54	49·71	21·10	49·61	21·32	49·52	21·53	49·43	21·75	55
55	50·63	21·49	50·53	21·71	50·44	21·93	50·34	22·15	54
56	51·55	21·88	51·45	22·11	51·36	22·33	51·26	22·55	56
57	52·47	22·27	52·37	22·50	52·27	22·73	52·17	22·96	57
58	53·39	22·66	53·29	22·90	53·19	23·13	53·09	23·36	58
59	54·31	23·05	54·21	23·29	54·11	23·53	54·00	23·76	59
60	55·23	23·44	55·13	23·68	55·02	23·92	54·92	24·16	60
61	56·15	23·83	56·05	24·08	55·94	24·32	55·83	24·57	61
62	57·07	24·23	56·97	24·47	56·86	24·72	56·75	24·97	62
63	57·99	24·62	57·88	24·87	57·77	25·12	57·66	25·37	63
64	58·91	25·01	58·80	25·26	58·69	25·52	58·58	25·78	64
65	59·83	25·40	59·72	25·66	59·61	25·92	59·50	26·18	65
66	60·75	25·79	60·64	26·05	60·53	26·32	60·41	26·58	66
67	61·67	26·18	61·56	26·45	61·44	26·72	61·33	26·98	67
68	62·59	26·57	62·48	26·84	62·36	27·11	62·24	27·39	68
69	63·51	26·96	63·40	27·24	63·28	27·51	63·16	27·79	69
70	64·44	27·35	64·32	27·63	64·19	27·91	64·07	28·19	70
71	65·36	27·74	65·23	28·03	65·11	28·31	64·99	28·59	71
72	66·28	28·13	66·15	28·42	66·03	28·71	65·90	29·00	72
73	67·20	28·52	67·07	28·82	66·95	29·11	66·82	29·40	73
74	68·12	28·91	67·99	29·21	67·86	29·51	67·73	29·80	74
75	69·04	29·30	68·91	29·61	68·78	29·91	68·65	30·21	75
76	69·96	29·70	69·83	30·00	69·70	30·30	69·56	30·61	76
77	70·88	30·09	70·75	30·40	70·61	30·70	70·48	31·01	77
78	71·80	30·48	71·67	30·79	71·53	31·10	71·39	31·41	78
79	72·72	30·87	72·58	31·18	72·45	31·50	72·31	31·82	79
80	73·64	31·26	73·50	31·58	73·36	31·90	73·22	32·22	80
81	74·56	31·65	74·42	31·97	74·28	32·30	74·14	32·62	81
82	75·48	32·04	75·34	32·37	75·20	32·70	75·06	33·03	82
83	76·40	32·43	76·26	32·76	76·12	33·10	75·97	33·43	83
84	77·32	32·82	77·18	33·16	77·03	33·49	76·89	33·83	84
85	78·24	33·21	78·10	33·55	77·95	33·89	77·80	34·23	85
86	79·16	33·60	79·02	33·95	78·87	34·29	78·72	34·64	86
87	80·08	33·99	79·93	34·34	79·78	34·69	79·63	35·04	87
88	81·00	34·38	80·85	34·74	80·70	35·09	80·55	35·44	88
89	81·92	34·78	81·77	35·13	81·62	35·49	81·46	35·84	89
90	82·85	35·17	82·69	35·53	82·54	35·89	82·38	36·25	90
91	83·77	35·56	83·61	35·92	83·45	36·29	83·29	36·65	91
92	84·69	35·95	84·53	36·32	84·37	36·68	84·21	37·05	92
93	85·61	36·34	85 45	36·71	85·29	37·08	85·12	37·46	93
94	86·53	36·73	86·37	37·11	86·20	37·48	86·04	37·86	94
95	87·45	37·12	87·29	37·50	87·12	37·88	86·95	38·26	95
96	88·37	37·51	88·20	37·90	88·04	38·28	87·87	38·66	96
97	89·29	37·90	89·12	38·29	88·95	38·68	88·79	39·07	97
98	90·21	38·29	90·04	38·68	89·87	39·08	89·70	39·47	98
99	91·13	38·68	90·96	39·08	90·79	39·48	90·62	39·87	99
100	92·05	39·07	91·88	39·47	91·71	39·87	91·53	40·27	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	67 Deg.		66¾ Deg.		66½ Deg.		66¼ Deg.		

Distance.	24 Deg.		24¼ Deg.		24½ Deg.		24¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·91	0·41	0·91	0·41	0·91	0·41	0·91	0·42	1
2	1·83	0·81	1·82	0·82	1·82	0·83	1·82	0·84	2
3	2·74	1·22	2·74	1·23	2·73	1·24	2·72	1·26	3
4	3·65	1·63	3·65	1·64	3·64	1·66	3·63	1·67	4
5	4·57	2·03	4·56	2·05	4·55	2·07	4·54	2·09	5
6	5·48	2·44	5·47	2·46	5·46	2·49	5·45	2·51	6
7	6·39	2·85	6·38	2·87	6·37	2·90	6·36	2·93	7
8	7·31	3·25	7·29	3·29	7·28	3·32	7·27	3·35	8
9	8·22	3·66	8·21	3·70	8·19	3·73	8·17	3·77	9
10	9·14	4·07	9·12	4·11	9·10	4·15	9·08	4·19	10
11	10·05	4·47	10·03	4·52	10·01	4·56	9·99	4·61	11
12	10·96	4·88	10·94	4·93	10·92	4·98	10·90	5·02	12
13	11·88	5·29	11·85	5·34	11·83	5·39	11·81	5·44	13
14	12·79	5·69	12·76	5·75	12·74	5·81	12·71	5·86	14
15	13·70	6·10	13·68	6·16	13·65	6·22	13·62	6·28	15
16	14·62	6·51	14·59	6·57	14·56	6·64	14·53	6·70	16
17	15·53	6·92	15·50	6·98	15·47	7·05	15·44	7·12	17
18	16·44	7·32	16·41	7·39	16·38	7·46	16·35	7·54	18
19	17·36	7·73	17·32	7·80	17·29	7·88	17·25	7·95	19
20	18·27	8·13	18·24	8·21	18·20	8·29	18·16	8·37	20
21	19·18	8·54	19·15	8·63	19·11	8·71	19·07	8·79	21
22	20·10	8·95	20·06	9·04	20·02	9·12	19·98	9·21	22
23	21·01	9·35	20·97	9·45	20·93	9·54	20·89	9·63	23
24	21·93	9·76	21·88	9·86	21·84	9·95	21·80	10·05	24
25	22·84	10·17	22·79	10·27	22·75	10·37	22·70	10·47	25
26	23·75	10·58	23·71	10·68	23·66	10·78	23·61	10·89	26
27	24·67	10·98	24·62	11·09	24·57	11·20	24·52	11·30	27
28	25·58	11·39	25·53	11·50	25·48	11·61	25·43	11·72	28
29	26·49	11·80	26·44	11·91	26·39	12·03	26·34	12·14	29
30	27·41	12·20	27·35	12·32	27·30	12·44	27·24	12·56	30
31	28·32	12·61	28·26	12·73	28·21	12·86	28·15	12·98	31
32	29·23	13·02	29·18	13·14	29·12	13·27	29·06	13·40	32
33	30·15	13·42	30·09	13·55	30·03	13·68	29·97	13·82	33
34	31·06	13·83	31·00	13·96	30·94	14·10	30·88	14·23	34
35	31·97	14·24	31·91	14·38	31·85	14·51	31·78	14·65	35
36	32·89	14·64	32·82	14·79	32·76	14·93	32·69	15·07	36
37	33·80	15·05	33·74	15·20	33·67	15·34	33·60	15·49	37
38	34·71	15·46	34·65	15·61	34·58	15·76	34·51	15·91	38
39	35·63	15·86	35·56	16·02	35·49	16·17	35·42	16·33	39
40	36·54	16·27	36·47	16·43	36·40	16·59	36·33	16·75	40
41	37·46	16·68	37·38	16·84	37·31	17·00	37·23	17·16	41
42	38·37	17·08	38·29	17·25	38·22	17·42	38·14	17·58	42
43	39·28	17·49	39·21	17·66	39·13	17·83	39·05	18·00	43
44	40·20	17·90	40·12	18·07	40·04	18·25	39·96	18·42	44
45	41·11	18·30	41·03	18·48	40·95	18·66	40·87	18·84	45
46	42·02	18·71	41·94	18·89	41·86	19·08	41·77	19·26	46
47	42·94	19·12	42·85	19·30	42·77	19·49	42·68	19·68	47
48	43·85	19·52	43·76	19·71	43·68	19·91	43·59	20·10	48
49	44·76	19·93	44·68	20·13	44·59	20·32	44·50	20·51	49
50	45·68	20·34	45·59	20·54	45·50	20·73	45·41	20·93	50
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
Distance.	66 Deg.		65¾ Deg.		65½ Deg.		65¼ Deg.		Distance.

Distance.	24 Deg.		24¼ Deg.		24½ Deg.		24¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	46·59	20·74	46·50	20·95	46·41	21·15	46·32	21·35	51
52	47·50	21·15	47·41	21·36	47·32	21·56	47·22	21·77	52
53	48·42	21·56	48·32	21·77	48·23	21·98	48·13	22·19	53
54	49·33	21·96	49·24	22·18	49·14	22·39	49·04	22·61	54
55	50·24	22·37	50.15	22·59	50·05	22·81	49·95	23·03	55
56	51·16	22·78	51·06	23·00	50·96	23·22	50·86	23·44	56
57	52·07	23·18	51·97	23·41	51·87	23·64	51·76	23·86	57
58	52·99	23·59	52·88	23·82	52·78	24·05	52·67	24·28	58
59	53·90	24·00	53·79	24·23	53·69	24·47	53·58	24·70	59
60	54·81	24·40	54·71	24·64	54·60	24·88	54·49	25·12	60
61	55·73	24·81	55·62	25·05	55·51	25·30	55·40	25·54	61
62	56·64	25·22	56·53	25·46	56·42	25·71	56·30	25·96	62
63	57·55	25·62	57·44	25·88	57·33	26·13	57·21	26·38	63
64	58·47	26·03	58·35	26·29	58·24	26·54	58·12	26·79	64
65	59·38	26·44	59·26	26·70	59·15	26·96	59·03	27·21	65
66	60·29	26·84	60·18	27·11	60·06	27·37	59·94	27·63	66
67	61·21	27·25	61·09	27·52	60·97	27·78	60·85	28·05	67
68	62·12	27·66	62·00	27·93	61·88	28·20	61·75	28·47	68
69	63·03	28·06	62·91	28·34	62·79	28·61	62·66	28·89	69
70	63·95	28·47	63·82	28·75	63·70	29·03	63·57	29·31	70
71	64·86	28·88	64·74	29·16	64·61	29·44	64·48	29·72	71
72	65·78	29·28	65·65	29·57	65·52	29·86	65·39	30·14	72
73	66·69	29·69	66·56	29·98	66·43	30·27	66·29	30·56	73
74	67·60	30·10	67·47	30·39	67·34	30·69	67·20	30·98	74
75	68·52	30·51	68·38	30·80	68·25	31·10	68·11	31·40	75
76	69·43	30·91	69·29	31·21	69·16	31·52	69·02	31·82	76
77	70·34	31·32	70·21	31·63	70·07	31·93	69·93	32·24	77
78	71·26	31·73	71·12	32·04	70·98	32·35	70·84	32·66	78
79	72·17	32·13	72·03	32·45	71·89	32·76	71·74	33·07	79
80	73·08	32·54	72·94	32·86	72·80	33·18	72·65	33·49	80
81	74·00	32·95	73·85	33·27	73·71	33·59	73·56	33·91	81
82	74·91	33·35	74·76	33·68	74·62	34·00	74·47	34·33	82
83	75·82	33·76	75·68	34·09	75·53	34·42	75·38	34·75	83
84	76·74	34·17	76·59	34·50	76·44	34·83	76·28	35·17	84
85	77·65	34·57	77·50	34·91	77·35	35·25	77·19	35·59	85
86	78·56	34·98	78·41	35·32	78·26	35·66	78·10	36·00	86
87	79·48	35·39	79·32	35·73	79·17	36·08	79·01	36·42	87
88	80·39	35·79	80·24	36·14	80·08	36·49	79·92	36·84	88
89	81·31	36·20	81·15	36·55	80·99	36·91	80·82	37·26	89
90	82·22	36·61	82·06	36·96	81·90	37·32	81·73	37·68	90
91	83·13	37·01	82·97	37·38	82·81	37·74	82·64	38·10	91
92	84·05	37·42	83·88	37·79	83·72	38·15	83·55	38·52	92
93	84·96	37·83	84·79	38·20	84·63	38·57	84·46	38·94	93
94	85·87	38·23	85·71	38·61	85·54	38·98	85·37	39·35	94
95	86·79	38·64	86·62	39·02	86·45	39·40	86·27	39·77	95
96	87·70	39·05	87·53	39·43	87·36	39·81	87·18	40·19	96
97	88·61	39·45	88·44	39·84	88.27	40·23	88·09	40·61	97
98	89·53	39·86	89·35	40·25	89·18	40·64	89·00	41·03	98
99	90·44	40·27	90·26	40·66	90·09	41·05	89·91	41·45	99
100	91·35	40·67	91·18	41·07	91·00	41·47	90·81	41·87	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	66 Deg.		65¾ Deg.		65½ Deg.		65¼ Deg.		

Distance.	25 Deg.		25¼ Deg.		25½ Deg.		25¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·91	0·42	0·90	0·43	0·90	0·43	0·90	0·43	1
2	1·81	0·85	1·81	0·85	1·81	0·86	1·80	0·87	2
3	2·72	1·27	2·71	1·28	2·71	1·29	2·70	1·30	3
4	3·63	1·69	3.62	1·71	3·61	1·72	3·60	1·74	4
5	4·53	2·11	4·52	2·13	4·51	2·15	4·50	2·17	5
6	5·44	2·54	5·43	2·56	5·42	2·58	5·40	2·61	6
7	6·34	2·96	6·33	2·99	6·32	3.01	6·30	3·04	7
8	7·25	3·38	7·24	3·41	7·22	3·44	7·21	3·48	8
9	8·16	3·80	8·14	3·84	8·12	3·87	8·11	3·91	9
10	9·06	4·23	9·04	4·27	9·03	4·31	9·01	4·34	10
11	9·97	4·65	9·95	4·69	9·93	4·74	9·91	4·78	11
12	10·88	5·07	10·85	5·12	10·83	5·17	10·81	5·21	12
13	11·78	5·49	11·76	5·55	11·73	5·60	11·71	5·65	13
14	12·69	5·92	12·66	5·97	12·64	6·03	12·61	6·08	14
15	13·59	6·34	13·57	6·40	13·54	6·46	13·51	6·52	15
16	14·50	6·76	14·47	6·83	14·44	6·89	14·41	6·95	16
17	15·41	7·18	15·38	7·25	15·34	7·32	15·31	7·39	17
18	16·31	7·61	16·28	7·68	16·25	7·75	16·21	7·82	18
19	17·22	8·03	17·18	8·10	17·15	8·18	17·11	8·25	19
20	18·13	8·45	18·09	8·53	18·05	8·61	18·01	8·69	20
21	19·03	8·87	18·99	8·96	18·95	9·04	18·91	9·12	21
22	19·94	9·30	19·90	9·38	19·86	9·47	19·82	9·56	22
23	20·85	9·72	20·80	9·81	20·76	9·90	20·72	9·99	23
24	21·75	10·14	21·71	10·24	21·66	10·33	21·62	10·43	24
25	22·66	10·57	22·61	10·66	22·56	10·76	22·52	10·86	25
26	23·56	10·99	23·52	11·09	23·47	11·19	23·42	11·30	26
27	24·47	11·41	24·42	11·52	24·37	11·62	24·32	11·73	27
28	25·38	11·83	25·32	11·94	25·27	12·05	25·22	12·16	28
29	26·28	12·26	26·23	12·37	26·17	12·48	26·12	12·60	29
30	27·19	12·68	27·13	12·80	27·08	12·92	27·02	13·03	30
31	28·10	13·10	28·04	13·22	27·98	13·35	27·92	13·47	31
32	29·00	13·52	28·94	13·65	28·88	13·78	28·82	13·90	32
33	29·91	13·95	29·85	14·08	29·79	14·21	29·72	14·34	33
34	30·81	14·37	30·75	14·50	30·69	14·64	30·62	14·77	34
35	31·72	14·79	31·66	14·93	31·59	15·07	31·52	15·21	35
36	32·63	15·21	32·56	15·36	32·49	15·50	32·43	15·64	36
37	33·53	15·64	33·46	15·78	33·40	15·93	33·33	16·07	37
38	34·44	16·06	34·37	16·21	34·30	16·36	34·23	16·51	38
39	35·35	16·48	35·27	16·64	35·20	16·79	35·13	16·94	39
40	36·25	16·90	36·18	17·06	36·10	17·22	36·03	17·38	40
41	37·16	17·33	37·08	17·49	37·01	17·65	36·93	17·81	41
42	38·06	17·75	37·99	17·92	37·91	18·08	37·83	18·25	42
43	38·97	18·17	38·89	18·34	38·81	18·51	38·73	18·68	43
44	39·88	18·60	39·80	18·77	39·71	18·94	39·63	19·12	44
45	40·78	19·02	40·70	19·20	40·62	19·37	40·53	19·55	45
46	41·69	19·44	41·60	19·62	41·52	19·80	41.43	19·98	46
47	42·60	19·86	42·51	20·05	42·42	20·23	42·33	20·42	47
48	43·50	20·29	43·41	20·48	43·32	20·66	43·23	20·85	48
49	44·41	20·71	44·32	20·90	44·23	21·10	44·13	21·29	49
50	45·32	21·13	45·22	21·33	45·13	21·53	45·03	21·72	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	65 Deg.		64¾ Deg.		64½ Deg.		64¼ Deg.		

Distance.	25 Deg. Lat.	25 Deg. Dep.	25¼ Deg. Lat.	25¼ Deg. Dep.	25½ Deg. Lat.	25½ Deg. Dep.	25¾ Deg. Lat.	25¾ Deg. Dep.	Distance.
51	46·22	21·55	46·13	21·75	46·03	21·96	45·94	22·16	51
52	47·13	21·98	47·03	22·18	46·93	22·39	46·84	22·59	52
53	48·03	22·40	47·94	22·61	47·84	22·82	47·74	23·03	53
54	48·94	22·82	48·84	23·03	48·74	23·25	48·64	23·46	54
55	49·85	23·24	49·74	23·46	49·64	23·68	49·54	23·89	55
56	50·75	23·67	50·65	23·89	50·54	24·11	50·44	24·33	56
57	51·66	24·09	51·55	24·31	51·45	24·54	51·34	24·76	57
58	52·57	24·51	52·46	24·74	52·35	24·97	52·24	25·20	58
59	53·47	24·93	53·36	25·17	53·25	25·40	53·14	25·63	59
60	54·38	25·36	54·27	25·59	54·16	25·83	54·04	26·07	60
61	55·28	25.78	55·17	26·02	55·06	26·26	54·94	26·50	61
62	56·19	26·20	56·08	26·45	55·96	26·69	55·84	26·94	62
63	57·10	26·62	56·98	26·87	56·86	27·12	56·74	27·37	63
64	58·00	27·05	57·89	27·30	57·77	27·55	57·64	27·80	64
65	58·91	27·47	58·79	27·73	58·67	27·98	58·55	28·24	65
66	59·82	27·89	59·69	28·15	59·57	28·41	59·45	28·67	66
67	60·72	28·32	60·60	28·58	60·47	28·84	60·35	29·11	67
68	61·63	28·74	61·50	29·01	61·38	29·27	61·25	29·54	68
69	62·54	29·16	62·41	29·43	62·28	29·71	62·15	29·98	69
70	63·44	29·58	63·31	29·86	63·18	30·14	63·05	30·41	70
71	64·35	30·01	64·22	30·29	64.08	30·57	63·95	30·85	71
72	65·25	30·43	65·12	30·71	64·99	31·00	64·85	31·28	72
73	66·16	30·85	66·03	31·14	65·89	31·43	65·75	31·71	73
74	67·07	31·27	66·93	31·57	66·79	31·86	66·65	32·15	74
75	67·97	31·70	67·83	31·99	67·69	32·29	67·55	32·58	75
76	68·88	32·12	68·74	32·42	68·60	32·72	68·45	33·02	76
77	69·79	32·54	69·64	32·85	69·50	33·15	69·35	33·45	77
78	70·69	32·96	70·55	33·27	70·40	33·58	70·25	33·89	78
79	71·60	33·39	71·45	33·70	71·30	34·01	71·16	34·32	79
80	72·50	33·81	72·36	34·13	72·21	34·44	72·06	34·76	80
81	73·41	34·23	73·26	34·55	73·11	34·87	72·96	35·19	81
82	74·32	34·65	74·17	34·98	74·01	35·30	73·86	35·62	82
83	75·22	35·08	75·07	35·41	74·91	35·73	74·76	36·06	83
84	76·13	35·50	75·97	35·83	75·82	36·16	75·66	36·49	84
85	77·04	35·92	76·88	36·26	76·72	36·59	76·56	36·93	85
86	77·94	36·35	77·78	36·68	77·62	37·02	77·46	37·36	86
87	78·85	36·77	78·69	37·11	78·52	37·45	78·36	37·80	87
88	79·76	37·19	79·59	37·54	79·43	37·88	79·26	38·23	88
89	80·66	37·61	80·50	37·96	80·33	38·32	80·16	38·67	89
90	81·57	38·04	81·40	38·39	81·23	38·75	81·06	39·10	90
91	82·47	38·46	82·31	38·82	82·14	39·18	81·96	39·53	91
92	83·38	38·88	83·21	39·24	83·04	39·61	82·86	39·97	92
93	84·29	39·30	84·11	39·67	83·94	40·04	83·76	40·40	93
94	85·19	39·73	85·02	40·10	84·84	40·47	84·67	40·84	94
95	86·10	40·15	85·92	40·52	85·75	40·90	85·57	41·27	95
96	87·01	40·57	86·83	40·95	86·65	41·33	86·47	41·71	96
97	87·91	40·99	87·73	41·38	87·55	41·76	87·37	42·14	97
98	88·82	41·42	88·64	41·80	87·45	42·19	88·27	42·58	98
99	89·72	41·84	89·54	42·23	89·36	42·62	89·17	43·01	99
100	90·63	42·26	90·45	42·66	90·26	43·05	90·07	43·44	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	65 Deg.		64¾ Deg.		64½ Deg.		64¼ Deg.		

Distance.	26 Deg.		26¼ Deg.		26½ Deg.		26¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·90	0·44	0·90	0·44	0·89	0·45	0·89	0·45	1
2	1·80	0·88	1·79	0·88	1·79	0·89	1·79	0·90	2
3	2·70	1·32	2·69	1·33	2·68	1·34	2·68	1·35	3
4	3·60	1·75	3·59	1·77	3·58	1·78	3·57	1·80	4
5	4·49	2·19	4·48	2·21	4·47	2·23	4·46	2·25	5
6	5·39	2·63	5·38	2·65	5·37	2·68	5·36	2·70	6
7	6·29	3·07	6·28	3·10	6·26	3·12	6·25	3·15	7
8	7·19	3·51	7·17	3·54	7·16	3·57	7·14	3·60	8
9	8·09	3·95	8·07	3·98	8·05	4·02	8·04	4·05	9
10	8·99	4·38	8·97	4·42	8·95	4·46	8·93	4·50	10
11	9·89	4·82	9·87	4·87	9·84	4·91	9·82	4·95	11
12	10·79	5·26	10·76	5·31	10·74	5·35	10·72	5·40	12
13	11·68	5·70	11·66	5·75	11·63	5·80	11·61	5·85	13
14	12·58	6·14	12·56	6·19	12·53	6·25	12·50	6·30	14
15	13·48	6·58	13·45	6·63	13·42	6·69	13·39	6·75	15
16	14·38	7·01	14·35	7·08	14·32	7·14	14·29	7·20	16
17	15·28	7·45	15·25	7·52	15·21	7·59	15·18	7·65	17
18	16·18	7·89	16·14	7·96	16·11	8·03	16·07	8·10	18
19	17·08	8·33	17·04	8·40	17·00	8·48	16·97	8·55	19
20	17·98	8·77	17·94	8·85	17·90	8·92	17·86	9·00	20
21	18·87	9·21	18·83	9·29	18·79	9·37	18·75	9·45	21
22	19·77	9·64	19·73	9·73	19·69	9·82	19·65	9·90	22
23	20·67	10·08	20·63	10·17	20·58	10·26	20·54	10·35	23
24	21·57	10·52	21·52	10·61	21·48	10·71	21·43	10·80	24
25	22·47	10·96	22·42	11·06	22·37	11·15	22·32	11·25	25
26	23·37	11·40	23·32	11·50	23·27	11·60	23·22	11·70	26
27	24·27	11·84	24·22	11·94	24·16	12·05	24·11	12·15	27
28	25·17	12·27	25·11	12·38	25·06	12·49	25·00	12·60	28
29	26·06	12·71	26·01	12·83	25·95	12·94	25·90	13·05	29
30	26·96	13·15	26·91	13·27	26·85	13·39	26·79	13·50	30
31	27·86	13·59	27·80	13·71	27·74	13·83	27·68	13·95	31
32	28·76	14·03	28·70	14·15	28·64	14·28	28·58	14·40	32
33	29·66	14·47	29·60	14·60	29·53	14·72	29·47	14·85	33
34	30·56	14·90	30·49	15·04	30·43	15·17	30·36	15·30	34
35	31·46	15·34	31·39	15·48	31·32	15·62	31·25	15·75	35
36	32·36	15·78	32·29	15·92	32·22	16·06	32·15	16·20	36
37	33·26	16·22	33·18	16·36	33·11	16·51	33·04	16·65	37
38	34·15	16·66	34·08	16·81	34·01	16·96	33·93	17·10	38
39	35·05	17·10	34·98	17·25	34·90	17·40	34·83	17·55	39
40	35·95	17·53	35·87	17·69	35·80	17·85	35·72	18·00	40
41	36·85	17·97	36·77	18·13	36·69	18·29	36·61	18·45	41
42	37·75	18·41	37·67	18·58	37·59	18·74	37·51	18·90	42
43	38·65	18·85	38·57	19·02	38·48	19·19	38·40	19·35	43
44	39·55	19·29	39·46	19·46	39·38	19·63	39·29	19·80	44
45	40·45	19·73	40·36	19·90	40·27	20·08	40·18	20·25	45
46	41·34	20·17	41·26	20·35	41·17	20·53	41·08	20·70	46
47	42·24	20·60	42·15	20·79	42·06	20·97	41·97	21·15	47
48	43·14	21·04	43·05	21·23	42·96	21·42	42·86	21·60	48
49	44·04	21·48	43·95	21·67	43·85	21·86	43·76	22·05	49
50	44·94	21·92	44·84	22·11	44·75	22·31	44·65	22·50	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	64 Deg.		63¾ Deg.		63½ Deg.		63¼ Deg.		

Distance.	26 Deg.		26¼ Deg.		26½ Deg.		26¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	45·84	22·36	45·74	22·56	45·64	22·76	45·54	22·96	51
52	46·74	22·80	46·64	23·00	46·54	23·20	46·43	23·41	52
53	47·64	23·23	47·53	23·44	47·43	23·65	47·33	23·86	53
54	48·53	23·67	48·43	23·88	48·33	24·09	48·22	24·31	54
55	49·43	24·11	49·33	24·33	49·22	24·54	49·11	24·76	55
56	50·33	24·55	50·22	24·77	50·12	24·99	50·01	25·21	56
57	51·23	24·99	51·12	25·21	51·01	25·43	50·90	25·66	57
58	52·13	25·43	52·02	25·65	51·91	25·88	51·79	26·11	58
59	53·03	25·86	52·92	26·09	52·80	26·33	52·69	26·56	59
60	53·93	26·30	53·81	26·54	53·70	26·77	53·58	27·01	60
61	54·83	26·74	54·71	26·98	54·59	27·22	54·47	27·46	61
62	55·73	27·18	55·61	27·42	55·49	27·66	55·36	27·91	62
63	56·62	27·62	56·50	27·86	56·38	28·11	56·26	28·36	63
64	57·52	28·06	57·40	28·31	57·28	28·56	57·15	28·81	64
65	58·42	28·49	58·30	28·75	58·17	29·00	58·04	29·26	65
66	59·32	28·93	59·19	29·19	59·07	29·45	58·94	29·71	66
67	60·22	29·37	60·09	29·63	59·96	29·90	59·83	30·16	67
68	61·12	29·81	60·99	30·08	60·86	30·34	60·72	30·61	68
69	62·02	30·25	61·88	30·52	61·75	30·79	61·62	31·06	69
70	62·92	30·69	62·78	30·96	62·65	31·23	62·51	31·51	70
71	63·81	31·12	63·68	31·40	63·54	31·68	63·40	31·96	71
72	64·71	31·56	64·57	31·84	64·44	32·13	64·29	32·41	72
73	65·61	32·00	65·47	32·29	65·33	32·57	65·19	32·86	73
74	66·51	32·44	66·37	32·73	66·23	33·02	66·08	33·31	74
75	67·41	32·88	67·27	33·17	67·12	33·46	66·97	33·76	75
76	68·31	33·32	68·16	33·61	68·01	33·91	67·87	34·21	76
77	69·21	33·75	69·06	34·06	68·91	34·36	68·76	34·66	77
78	70·11	34·19	69·96	34·50	69·80	34·80	69·65	35·11	78
79	71·00	34·63	70·85	34·94	70·70	35·25	70·55	35·56	79
80	71·90	35·07	71·75	35·38	71·59	35·70	71·44	36·01	80
81	72·80	35·51	72·65	35·83	72·49	36·14	72·33	36·46	81
82	73·70	35·95	73·54	36·27	73·38	36·59	73·22	36·91	82
83	74·60	36·38	74·44	36·71	74·28	37·03	74·12	37·36	83
84	75·50	36·82	75.34	37·15	75·17	37·48	75·01	37·81	84
85	76·40	37·26	76·23	37·59	76·07	37·93	75·90	38·26	85
86	77·30	37·70	77·13	38·04	76·96	38·37	76·80	38·71	86
87	78·20	38·14	78·03	38·48	77·86	38·82	77·69	39·16	87
88	79·09	38·58	78·92	38·92	78·75	39·27	78·58	39·61	88
89	79·99	39·01	79·82	39·36	79·65	39·71	79·48	40·06	89
90	80·89	39·45	80·72	39·81	80·54	40·16	80·37	40·51	90
91	81·79	39·89	81·62	40·25	81·44	40·60	81·26	40·96	91
92	82·69	40·33	82·51	40·69	82·33	41·05	82·15	41·41	92
93	83·59	40·77	83·41	41·13	83·23	41·50	83·05	41·86	93
94	84·49	41·21	84·31	41·58	84·12	41·94	83·94	42·31	94
95	85·39	41·65	85·20	42·02	85·02	42·39	84·83	42·76	95
96	86·28	42·08	86·10	42·46	85·91	42·83	85·73	43·21	96
97	87·18	42·52	87·00	42·90	86·81	43·28	86·62	43·66	97
98	88·08	42·96	87·89	43·34	87·70	43·73	87·51	44·11	98
99	88·98	43·40	88·79	43·79	88·60	44·17	88·40	44·56	99
100	89·88	43·84	89·69	44·23	89·49	44·62	89·30	45·01	100
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
Distance.	64 Deg.		63¾ Deg.		63½ Deg.		63¼ Deg.		Distance.

Distance.	27 Deg.		27¼ Deg.		27½ Deg.		27¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·89	0·45	0·89	0·46	0·89	0·46	0·88	0·47	1
2	1·78	0·91	1·78	0·92	1·77	0·92	1·77	0·93	2
3	2·67	1·36	2·67	1·37	2·66	1·39	2·65	1·40	3
4	3·56	1·82	3·56	1·83	3·55	1·85	3·54	1·86	4
5	4·45	2·27	4·45	2·29	4·44	2·31	4·42	2·33	5
6	5·35	2·72	5·33	2·75	5·32	2·77	5·31	2·79	6
7	6·24	3·18	6·22	3·21	6·21	3·23	6·19	3·26	7
8	7·13	3·63	7·11	3·66	7·10	3·69	7·08	3·72	8
9	8·02	4·09	8·00	4·12	7·98	4·16	7·96	4·19	9
10	8·91	4·54	8·89	4·58	8·87	4·62	8·85	4·66	10
11	9·80	4·99	9·78	5·04	9·76	5·08	9·73	5·12	11
12	10·69	5·45	10·67	5·49	10·64	5·54	10·62	5·59	12
13	11·58	5·90	11·56	5·95	11·53	6·00	11·50	6·05	13
14	12·47	6·36	12·45	6·41	12·42	6·46	12·39	6·52	14
15	13·37	6·81	13·34	6·87	13·31	6·93	13·27	6·98	15
16	14·26	7·26	14·22	7·33	14·19	7·39	14·16	7·45	16
17	15·15	7·72	15·11	7·78	15·08	7·85	15·04	7·92	17
18	16·04	8·17	16·00	8·24	15·97	8·31	15·93	8·38	18
19	16·93	8·63	16·89	8·70	16·85	8·77	16·81	8·85	19
20	17·82	9·08	17·78	9·16	17·74	9·23	17·70	9·31	20
21	18·71	9·53	18·67	9·62	18·63	9·70	18·58	9·78	21
22	19·60	9·99	19·56	10·07	19·51	10·16	19·47	10·24	22
23	20·49	10·44	20·45	10·53	20·40	10·62	20·35	10·71	23
24	21·38	10·90	21·34	10·99	21·29	11·08	21·24	11·17	24
25	22·28	11·35	22·23	11·45	22·18	11·54	22·12	11·64	25
26	23·17	11·80	23·11	11·90	23·06	12·01	23·01	12·11	26
27	24·06	12·26	24·00	12·36	23·95	12·47	23·89	12·57	27
28	24·95	12·71	24·89	12·82	24·84	12·93	24·78	13·04	28
29	25·84	13·17	25·78	13·28	25·72	13·39	25·66	13·50	29
30	26·73	13·62	26·67	13·74	26·61	13·85	26·55	13·97	30
31	27·62	14·07	27·56	14·19	27.50	14·31	27·43	14·43	31
32	28·51	14·53	28·45	14·65	28·38	14·78	28·32	14·90	32
33	29·40	14·98	29·34	15·11	29·27	15·24	29·20	15·37	33
34	30·29	15·44	30·23	15·57	30·16	15·70	30·09	15·83	34
35	31·19	15·89	31·12	16·03	31·05	16·16	30·97	16·30	35
36	32·08	16·34	32·00	16·48	31·93	16·62	31·86	16·76	36
37	32·97	16·80	32·89	16·94	32·82	17·08	32·74	17·23	37
38	33·86	17·25	33·78	17·40	33·71	17·55	33·63	17·69	38
39	34·75	17·71	34·67	17·86	34·59	18·01	34·51	18·16	39
40	35·64	18·16	35·56	18·31	35·48	18·47	35·40	18·62	40
41	36·53	18·61	36·45	18·77	36·37	18·93	36·28	19·09	41
42	37·42	19·07	37·34	19·23	37·25	19·39	37·17	19·56	42
43	38·31	19·52	38·23	19·69	38·14	19·86	38·05	20·02	43
44	39·20	19·98	39·12	20·15	39·03	20·32	38·94	20·49	44
45	40·10	20·43	40·01	20·60	39·92	20·78	39·82	20·95	45
46	40·99	20·88	40·89	21·06	40·80	21·24	40·71	21·42	46
47	41·88	21·34	41·78	21·52	41·69	21·70	41·59	21·88	47
48	42·77	21·79	42·67	21·98	42·58	22·16	42·48	22·35	48
49	43·66	22·25	43·56	22·44	43·46	22·63	43·36	22·82	49
50	44·55	22·70	44·45	22·89	44·35	23·09	44·25	23·28	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	63 Deg.		62¾ Deg.		62½ Deg.		62¼ Deg.		

Distance.	27 Deg.		27¼ Deg.		27½ Deg.		27¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	45·44	23·15	45·34	23·35	45·24	23·55	45·13	23·75	51
52	46·33	23·61	46·23	23·81	46·12	24·01	46·02	24·21	52
53	47·22	24·06	47·12	24·27	47·01	24·47	46·90	24·68	53
54	48·11	24·52	48·01	24·73	47·90	24·93	47·79	25·14	54
55	49·01	24·97	48·90	25·18	48·79	25·40	48·67	25·61	55
56	49·90	25·42	49·78	25·64	49·67	25·86	49·56	26·07	56
57	50·79	25·88	50·67	26·10	50·56	26·32	50·44	26·54	57
58	51·68	26·33	51·56	26·56	51·45	26·78	51·33	27·01	58
59	52·57	26·79	52·45	27·01	52·33	27·24	52·21	27·47	59
60	53·46	27·24	53·34	27·47	53·22	27·70	53·10	27·94	60
61	54·35	27·69	54·23	27·93	54·11	28·17	53·98	28·40	61
62	55·24	28·15	55·12	28·39	54·99	28·63	54·87	28·87	62
63	56·13	28·60	56·01	28·85	55·88	29·00	55·75	29·33	63
64	57·02	29·06	56·90	29·30	56·77	29·55	56·64	29·80	64
65	57·92	29·51	57·79	29·76	57·66	30·01	57·52	30·26	65
66	58·81	29·96	58·68	30·22	58·54	30·48	58·41	30·73	66
67	59·70	30·42	59·56	30·68	59·43	30·94	59·29	31·20	67
68	60·59	30·87	60·45	31·14	60·32	31·40	60·18	31·66	68
69	61·48	31·33	61·34	31·59	61·20	31·86	61·06	32·13	69
70	62·37	31·78	62·23	32·05	62·09	32·32	61·95	32·59	70
71	73·26	32·23	63·12	32·51	62·98	32·78	62·83	33·06	71
72	64·15	32·69	64·01	32·97	63·86	33·25	63·72	33·52	72
73	65·04	33·14	64·90	33·42	64·75	33·71	64·60	33·99	73
74	65·93	33·60	65·79	33·88	65·64	34·17	65·49	34·46	74
75	66·83	34·05	66·68	34·34	66·53	34·63	66·37	34·92	75
76	67·72	34·50	67·57	34·80	67·41	35·09	67·26	35·39	76
77	68·61	34·96	68·45	35·26	68·30	35·55	68·14	35·85	77
78	69·50	35·41	69·34	35·71	69·19	36·02	69·03	36·32	78
79	70·39	35·87	70·23	36·17	70·07	36·48	69·91	36·78	79
80	71·28	36·32	71·12	36·63	70·96	36·94	70·80	37·25	80
81	72·17	36·77	72·01	37·09	71·85	37·40	71·68	37·71	81
82	73·06	37·23	72·90	37·55	72·73	37·86	72·57	38·18	82
83	73·95	37·68	73·79	38·00	73·62	38·33	73·45	38·65	83
84	74·84	38·14	74·68	38·46	74·51	38·79	74·34	39·11	84
85	75·74	38·59	75·57	38·92	75·40	39·25	75·22	39·58	85
86	76·63	39·04	76·46	39·38	76·28	39·71	76·11	40·04	86
87	77·52	39·50	77·34	39·83	77·17	40·17	76·99	40·51	87
88	78·41	39·95	78·23	40·29	78·06	40·63	77·88	40·97	88
89	79·30	40·41	79·12	40·75	78·94	41·10	78·76	41·44	89
90	80·19	40·86	80·01	41·21	79·83	41·56	79·65	41·91	90
91	81·08	41·31	80·90	41·67	80·72	42·02	80·53	42·37	91
92	81·97	41·77	81·79	42·12	81·60	42·48	81·42	42·84	92
93	82·86	42·22	82·68	42·58	82·49	42·94	82·30	43·30	93
94	83·75	42·68	83·57	43·04	83·38	43·40	83·19	43·77	94
95	84·65	43·13	84·46	43·59	84·27	43·87	84·07	44·23	95
96	85·54	43·58	85·35	43·96	85·15	44·33	84·96	44·70	96
97	86·43	44·04	86·23	44·41	86·04	44·79	85·84	45·16	97
98	87·32	44·49	87.12	44·87	86·93	45·25	86·73	45·63	98
99	88·21	44·95	88·01	45·33	87·81	45·71	87·61	46·10	99
100	89·10	45·40	88·90	45·79	88·70	46·17	88·50	46·56	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	[illegible]
	63 Deg.		62¾ Deg.		62½ D[illegible]		[illegible]		

Distance.	28 Deg.		28¼ Deg.		28½ Deg.		28¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·88	0·47	0·88	0·47	0·88	0·48	0·88	0·48	1
2	1·77	0·94	1·76	0·95	1·76	0·95	1·75	0·96	2
3	2·65	1·41	2·64	1·42	2·64	1·43	2·63	1·44	3
4	3·53	1·88	3·52	1·89	3·52	1·91	3·51	1.92	4
5	4·41	2·35	4·40	2·37	4·39	2·39	4·38	2·40	5
6	5·30	2·82	5·29	2·84	5·27	2·86	5·26	2·89	6
7	6·18	3·29	6·17	3·31	6·15	3·34	6·14	3·37	7
8	7·06	3·76	7·05	3·79	7·03	3·82	7·01	3·85	8
9	7·95	4·23	7·93	4·26	7·91	4·29	7·89	4·33	9
10	8·83	4·69	8·81	4·73	8·79	4·77	8·77	4·81	10
11	9·71	5·16	9·69	5·21	9·67	5·25	9·64	5·29	11
12	10·60	5·63	10·57	5·68	10·55	5·73	10·52	5·77	12
13	11·48	6·10	11·45	6·15	11·42	6·20	11·40	6·25	13
14	12·36	6·57	12·33	6·63	12·30	6·68	12·27	6·73	14
15	13·24	7·04	13·21	7·10	13·18	7·16	13·15	7·21	15
16	14·13	7·51	14·09	7·57	14·06	7·63	14·03	7·70	16
17	15·01	7·98	14·98	8·05	14·94	8·11	14·90	8·18	17
18	15·89	8·45	15·86	8·52	15·82	8·59	15·78	8·66	18
19	16·78	8·92	16·74	8·99	16·70	9·07	16·66	9·14	19
20	17·66	9·39	17·62	9·47	17·58	9·54	17·53	9·62	20
21	18·54	9·86	18·50	9·94	18·46	10·02	18·41	10·10	21
22	19·42	10·33	19·38	10·41	19·33	10·50	19·29	10·58	22
23	20·31	10·80	20·26	10·89	20·21	10·97	20·16	11·06	23
24	21·19	11·27	21·14	11·36	21·09	11·45	21·04	11·54	24
25	22·07	11·74	22·02	11·83	21·97	11·93	21·92	12·02	25
26	22·96	12·21	22·90	12·31	22·85	12·41	22·79	12·51	26
27	23·84	12·68	23·78	12·78	23·73	12·88	23·67	12·99	27
28	24·72	13·15	24·66	13·25	24·61	13·36	24·55	13·47	28
29	25·61	13·61	25·55	13·73	25·49	13·84	25·43	13·95	29
30	26·49	14·08	26·43	14·20	26·36	14·31	26·30	14·43	30
31	27·37	14·55	27·31	14·67	27·24	14·79	27·18	14·91	31
32	28·25	15·02	28·19	15·15	28·12	15·27	28·06	15·39	32
33	29·14	15·49	29·07	15·62	29·00	15·75	28·93	15·87	33
34	30·02	15·96	29·95	16·09	29·88	16·22	29·81	16·35	34
35	30·90	16·43	30·83	16·57	30·76	16·70	30·69	16·83	35
36	31·79	16·90	31·71	17·04	31·64	17·18	31·56	17·32	36
37	32·67	17·37	32·59	17·51	32·52	17·65	32·44	17·80	37
38	33·55	17·84	33·47	17·99	33·39	18·13	33·32	18·28	38
39	34·43	18·31	34·35	18·46	34·27	18·61	34·19	18·76	39
40	35·32	18·78	35·24	18·93	35·15	19·09	35·07	19·24	40
41	36·20	19·25	36·12	19·41	36·03	19·56	35·95	19·72	41
42	37·08	19·72	37·00	19·88	36·91	20·04	36·82	20·20	42
43	37·97	20·19	37·88	20·35	37·79	20·52	37·70	20·68	43
44	38·85	20·66	38·76	20·83	38·67	20·99	38·58	21·16	44
45	39·73	21·13	39·64	21·30	39·55	21·47	39·45	21·64	45
46	40·62	21·60	40·52	21·77	40·43	21·95	40·33	22·13	46
47	41·50	22·07	41·40	22·25	41·30	22·43	41·21	22·61	47
48	42·38	22·53	43·28	22·72	42·18	22·90	42·08	23·09	48
49	43·26	23·00	43·16	23·19	43·06	23·38	42·96	23·57	49
50	44·15	23·47	44·04	23·67	43·94	23·86	43·84	24·05	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	62 Deg.		61¾ Deg.		61½ Deg.		61¼ Deg.		

Distance.	28 Deg. Lat.	28 Deg. Dep.	28¼ Deg. Lat.	28¼ Deg. Dep.	28½ Deg. Lat.	28½ Deg. Dep.	28¾ Deg. Lat.	28¾ Deg. Dep.	Distance.
51	45·03	23·94	44·93	24·14	44·82	24·34	44·71	24·53	51
52	45·91	24·41	45·81	24·61	45·70	24·81	45·59	25·01	52
53	46·80	24·88	46·69	25·09	46·58	25·29	46·47	25·49	53
54	47·68	25·35	47·57	25·56	47·46	25·77	47·34	25·97	54
55	48·56	25·82	48·45	26·03	48·33	26·24	48·22	26·45	55
56	49·45	26·29	49·33	26·51	49·21	26·72	49·10	26·94	56
57	50·33	26·76	50·21	26·98	50·09	27·20	49·97	27·42	57
58	51·21	27·23	51·09	27·45	50·97	27·68	50·85	27·90	58
59	52·09	27·70	51·97	27·93	51·85	28·15	51·73	28·38	59
60	52·98	28·17	52·85	28·40	52·73	28·63	52·60	28·86	60
61	53·86	28·64	53·73	28·87	53·61	29·11	53·48	29·34	61
62	54·74	29·11	54·62	29·35	54·49	29·58	54·36	29·82	62
63	55·63	29·58	55·50	29·82	55·37	30·06	55·23	30·30	63
64	56·51	30·05	56·38	30·29	56·24	30·54	56·11	30·78	64
65	57·39	30·52	57·26	30·77	57·12	31·02	56·99	31·26	65
66	58·27	30·99	58·14	31·24	58·00	31·49	57·86	31·75	66
67	59·16	31·45	59·02	31·71	58·88	31·97	58·74	32·23	67
68	60·04	31·92	59·90	32·19	59·76	32·45	59·62	32·71	68
69	60·92	32·39	60·78	32·66	60·64	32·92	60·49	33·19	69
70	61·81	32·86	61·66	33·13	61·52	33·40	61·37	33·67	70
71	62·69	33·33	62·54	33·61	62·40	33·88	62·25	34·15	71
72	63·57	33·80	63·42	34·08	63·27	34·36	63·12	34·63	72
73	64·46	34·27	64·30	34·55	64·15	34·83	64·00	35·11	73
74	65·34	34·74	65·19	35·03	65·03	35·31	64·88	35·59	74
75	66·22	35·21	66·07	35.50	65·91	35·79	65·75	36·07	75
76	67·10	35·68	66·95	35·97	66·79	36·26	66·63	36·56	76
77	67·99	36·15	67·83	36·45	67·67	36·74	67·51	37·04	77
78	68·87	36·62	68·71	36·92	68·55	37·22	68·38	37·52	78
79	69·75	37·09	69·59	37·39	69·43	37·70	69·26	38·00	79
80	70·64	37·56	70·47	37·87	70·31	38·17	70·14	38·48	80
81	71·52	38·03	71·35	38·34	71·18	38·65	71·01	38·96	81
82	72·40	38·50	72·23	38·81	72·06	39·13	71·89	39·44	82
83	73·28	38·97	73·11	39·29	72·94	39·60	72·77	39·92	83
84	74·17	39·44	73·99	39·76	73·82	40·08	73·64	40·40	84
85	75·05	39·91	74·88	40·23	74·70	40·56	74·52	40·88	85
86	75·93	40·37	75·76	40·71	75·58	41·04	75·40	41·36	86
87	76·82	40·84	76·64	41·18	76·46	41·51	76·28	41·85	87
88	77·70	41·31	77·52	41·65	77·34	41·99	77·15	42·33	88
89	78·58	41·78	78·40	42·13	78·21	42·47	78·03	42·81	89
90	79·47	42·25	79·28	42·60	79·09	42·94	78·91	43·29	90
91	80·35	42·72	80·16	43·07	79·97	43·42	79·78	43·77	91
92	81·23	43·19	81·04	43·55	80·85	43·90	80·66	44·25	92
93	82·11	43·66	81·92	44·02	81·73	44·38	81·54	44·73	93
94	83·00	44·13	82·80	44·49	82·61	44·85	82·41	45·21	94
95	83·88	44·60	83·68	44·97	83·49	45·33	83·29	45·69	95
96	84·76	45·07	84·57	45·44	84·37	45·81	84·17	46·17	96
97	85·65	45·54	85·45	45·91	85·25	46·28	85·04	46·66	97
98	86·53	46·01	86·33	46·39	86·12	46·76	85·92	47·14	98
99	87·41	46·48	87·21	46·86	87·00	47·24	86·80	47·62	99
100	88·29	46·95	88·09	47·33	87·88	47·72	87·67	48·10	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	62 Deg.		61¾ Deg.		61½ Deg.		61¼ Deg.		

Distance.	29 Deg. Lat.	29 Deg. Dep.	29¼ Deg. Lat.	29¼ Deg. Dep.	29½ Deg. Lat.	29½ Deg. Dep.	29¾ Deg. Lat.	29¾ Deg. Dep.	Distance.
1	0·87	0·48	0·87	0·49	0·87	0·49	0·87	0·50	1
2	1·75	0·97	1·74	0·98	1·74	0·98	1·74	0·99	2
3	2·62	1·45	2·62	1·47	2·61	1·48	2·60	1·49	3
4	3·50	1·94	3·49	1·95	3·48	1·97	3·47	1·98	4
5	4·37	2·42	4·36	2·44	4·35	2·46	4·34	2·48	5
6	5·25	2·91	5·23	2·93	5·22	2·95	5·21	2·98	6
7	6·12	3·39	6·11	3·42	6·09	3·45	6·08	3·47	7
8	7·00	3·88	6·98	3·91	6·96	3·94	6·95	3·97	8
9	7·87	4·36	7·85	4·40	7·83	4·43	7·81	4·47	9
10	8·75	4·85	8·72	4·89	8·70	4·92	8·68	4·96	10
11	9·62	5·33	9·60	5·37	9·57	5·52	9·55	5·46	11
12	10·50	5·82	10·47	5·86	10·44	5·91	10·42	5·94	12
13	11·37	6·30	11·34	6·35	11·31	6·40	11·29	6·45	13
14	12·24	6·79	12·21	6·84	12·18	6·89	12·15	6·95	14
15	13·12	7·27	13·09	7·33	13·06	7·39	13·02	7·44	15
16	13·99	7·76	13·96	7·82	13·93	7·88	14·89	7·94	16
17	14·87	8·24	14·83	8·31	14·80	8·37	14·76	8·44	17
18	15·74	8·73	15·70	8·80	15·67	8·86	15·63	8·93	18
19	16·62	9·21	16·58	9·28	16·54	9·36	16·50	9·43	19
20	17·49	9·70	17·45	9·77	17·41	9·85	17·36	9·92	20
21	18·37	10·18	18·32	10·26	18·28	10·34	18·23	10·42	21
22	19·24	10·67	19·19	10·75	19·15	10·83	19 10	10·92	22
23	20·12	11·15	20·07	11·24	20·02	11·33	20·97	11·41	23
24	20·99	11·64	20·94	11·73	20·89	11·82	21·84	11·91	24
25	21·87	12·12	21·81	12·22	21·76	12·31	21·70	12·41	25
26	22·74	12·60	22·68	12·70	22·63	12·80	22·57	12·90	26
27	23·61	13·09	23·56	13·19	23·50	13·30	23·44	13·40	27
28	24·49	13·57	24·43	13·68	24·37	13·79	24·31	13·89	28
29	25·36	14·06	25·30	14·17	25·24	14·28	25·18	14·39	29
30	26·24	14·54	26·17	14·66	26·11	14·77	26·05	14·89	30
31	27·11	15·03	27·05	15·15	26·98	15·27	26·91	15·38	31
32	27·99	15·51	27·92	15·64	27·85	15·76	27·78	15·88	32
33	28·86	16·00	28·79	16·12	28·72	16·25	28·65	16·38	33
34	29·74	16·48	29·66	16·61	29·59	16·74	29·52	16·87	34
35	30·61	16·97	30·54	17·10	30·46	17·23	30·89	17·37	35
36	31·49	17·45	31·41	17·59	31.83	17·73	31·26	17·86	36
37	32·36	17·94	32·28	18·08	32.20	18·22	32·12	18·36	37
38	33·24	18·42	33·15	18·57	33·07	18·71	32·99	18·86	38
39	34·11	18·91	34·03	19·06	33·94	19.20	33·86	19·35	39
40	34·98	19·39	34·90	19·54	34·81	19·70	34·73	19·85	40
41	35·86	19·88	35·77	20·03	35·68	20·19	35 60	20·34	41
42	36·73	20·36	36·64	20·52	36·55	20·68	36·46	20·84	42
43	37·61	20·85	37·52	21·01	37·43	21·17	37·33	21·34	43
44	38·48	21·33	38·39	21·50	38·30	21·67	38·20	21·83	44
45	39·36	21·82	39·26	21·99	39·17	22·16	39·07	22·33	45
46	40·23	22·30	40·13	22·48	40·04	22·65	39·94	22·83	46
47	41·11	22·79	41·01	22·97	40·91	23·14	40·81	23·32	47
48	41·98	23·27	41·88	23·45	41·78	23·63	41·67	23·82	48
49	42·86	23·76	42·75	23·94	42·65	24·13	42·54	24·31	49
50	43·73	24·24	43·62	24·43	43·52	24·62	43·41	24·81	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep	Lat.	Dep.	Lat.	Distance.
	61 Deg.		60¾ Deg.		60½ Deg		60¼ Deg.		

Distance.	29 Deg.		29¼ Deg.		29½ Deg.		29¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	44·61	24·73	44·50	24·92	44·39	25·11	44·28	25·31	51
52	45·48	25·21	45·37	25·41	45·26	25·61	45·15	25·80	52
53	46·35	25·69	46·24	25·90	46·13	26·10	46·01	26·30	53
54	47·23	26·18	47·11	26·39	47·00	26·59	46·88	26·80	54
55	48·10	26·66	47·99	26·87	47·87	27·08	47·75	27·29	55
56	48·98	27·15	48·86	27·36	48·74	27·58	48·62	27·79	56
57	49·85	27·63	49·73	27·85	49·61	28·07	49·49	28·28	57
58	50·73	28·12	50·60	28·34	50·48	28·56	50·36	28·78	58
59	51·60	28·60	51·48	28·83	51·35	29·05	51·22	29·28	59
60	52·48	29·09	52·35	29·32	52·22	29·55	52·09	29·77	60
61	53·35	29·57	53·22	29·81	53·09	30·04	52·96	30·27	61
62	54·23	30·06	54·09	30·29	53·96	30·53	53·83	30·77	62
63	55·10	30·54	54·97	30·78	54·83	31·02	54·70	31·26	63
64	55·98	31·03	55·84	31·27	55·70	31·52	55·56	31·76	64
65	56·85	31·51	56·71	31·76	56·57	32·01	56·43	32·25	65
66	57·72	32·00	57·58	32·25	57·44	32·50	57·30	32·75	66
67	58·60	32·48	58·46	32·74	58·31	32·99	58·17	33·25	67
68	59·47	32·97	59·33	33·23	59·18	33·48	59·04	33·74	68
69	60·35	33·45	60·20	33·71	60·05	33·98	59·91	34·24	69
70	61·22	33·94	61·07	34·20	60·92	34·47	60·77	34·74	70
71	62·10	34·42	61·95	34·69	61·80	34·96	61·64	35·23	71
72	62·97	34·91	62·82	35·18	62·67	35·45	62·51	35·73	72
73	63·85	35·39	63·69	35·67	63·54	35·95	63·38	36·22	73
74	64·72	35·88	64·56	36·16	64·41	36·44	64·25	36·72	74
75	65·60	36·36	65·44	36·65	65·28	36·93	65·11	37·22	75
76	66·47	36·85	66·31	37·14	66·15	37·42	65·98	37·71	76
77	67·35	37·33	67·18	37·62	67·02	37·92	66·85	38·21	77
78	68·22	37·82	68·05	38·11	67·89	38·41	67·72	38·70	78
79	69·09	38·30	68·93	38·60	68·76	38·90	68·59	39·20	79
80	69·97	38·78	69·80	39·09	69·63	39·39	69·46	39·70	80
81	70·84	39·27	70·67	39·58	70·50	39·89	70·32	40·19	81
82	71·72	39·75	71·54	40·07	71·37	40·38	71·19	40·69	82
83	72·59	40·24	72·42	40·56	72·24	40·87	72·06	41·19	83
84	73·47	40·72	73·29	41·04	73·11	41·36	72·93	41·68	84
85	74·34	41·21	74·16	41·53	73·98	41·86	73·80	42·18	85
86	75·22	41·69	75·03	42·02	74·85	42·35	74·67	42·67	86
87	76·09	42·18	75·91	42·51	75·72	42·84	75·53	43·17	87
88	76·97	42·66	76·78	43·00	76·59	43·33	76·40	43·67	88
89	77·84	43·15	77·65	43·49	77·46	43·83	77·27	44·16	89
90	78·72	43·63	78·52	43·98	78·33	44·32	78·14	44·66	90
91	79·59	44·12	79·40	44·46	79·20	44·81	79·01	45·16	91
92	80·46	44·60	80·27	44·95	80·07	45·30	79·87	45·65	92
93	81·34	45·09	81·14	45·44	80·94	45·80	80·74	46·15	93
94	82·21	45·57	82·01	45·93	81·81	46·29	81·61	46·64	94
95	83·09	46·06	82·89	46·42	82·68	46·78	82·48	47·14	95
96	83·96	46·54	83·76	46·91	83·55	47·27	83·35	47·64	96
97	84·84	47·03	84·63	47·40	84·42	47·77	84·22	48·13	97
98	85·71	47·51	85·50	47·88	85·29	48·26	85·08	48·63	98
99	86·59	48·00	86·38	48·37	86·17	48·75	85·95	49·13	99
100	87·46	48·48	87·25	48·86	87·04	49·24	86·82	49·62	100
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
Distance.	61 Deg.		60¾ Deg.		60½ Deg.		60¼ Deg.		Distance.

Distance.	30 Deg. Lat.	30 Deg. Dep.	30¼ Deg. Lat.	30¼ Deg. Dep.	30½ Deg. Lat.	30½ Deg. Dep.	30¾ Deg. Lat.	30¾ Deg. Dep.	Distance.
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0·86	0·51	1
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1·72	1·02	2
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2·58	1·53	3
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3·44	2·05	4
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4·30	2·56	5
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5·16	3·07	6
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6·02	3·58	7
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6·88	4·09	8
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7·73	4·60	9
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8·59	5·11	10
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9·45	5·62	11
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10·31	6·14	12
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11·17	6·65	13
14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12·03	7·16	14
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12·89	7·67	15
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13·75	8·18	16
17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14·61	8·69	17
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15·47	9·20	18
19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16·33	9·71	19
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17·19	10·23	20
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18·05	10·74	21
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18·91	11·25	22
23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19·77	11·76	23
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20·63	12·27	24
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21·49	12·78	25
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	22·34	13·29	26
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	23·20	13·80	27
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24·06	14·32	28
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24·92	14·83	29
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25·78	15·34	30
31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	26·64	15·85	31
32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	27·50	16·36	32
33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	28·36	16·87	33
34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	29·22	17·38	34
35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30·08	17·90	35
36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30·94	18·41	36
37	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31·80	18·92	37
38	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	32·66	19·43	38
39	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	33·52	19·94	39
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	34·38	20·45	40
41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	35·24	20·96	41
42	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	36·10	21·47	42
43	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	36·95	21·99	43
44	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	37·81	22·50	44
45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	38·67	23·01	45
46	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	39·53	23·52	46
47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	40·39	24·03	47
48	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	41·25	24·54	48
49	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	42·11	25·05	49
50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	42·97	25·56	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	60 Deg.		59¾ Deg.		59½ Deg.		59¼ Deg.		

Distance.	30 Deg.		30¼ Deg.		30½ Deg.		30¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	44·17	25·50	44·06	25·69	43·94	25·88	43·83	26·08	51
52	45·03	26·00	44·92	26·20	44·80	26·39	44·69	26·59	52
53	45·90	26·50	45·78	26·70	45·67	26·90	45·55	27·10	53
54	46·77	27·00	46·65	27·20	46·53	27·41	46·41	27·61	54
55	47·63	27·50	47·51	27·71	47·39	27·91	47·27	28·12	55
56	48·50	28·00	48·37	28·21	48·25	28·42	48·13	28·63	56
57	49·36	28·50	49·24	28·72	49·11	28·93	48·99	29·14	57
58	50·23	29·00	50·10	29·22	49·97	29·44	49·85	29·65	58
59	51·10	29·50	50·97	29·72	50·84	29·94	50·70	30·17	59
60	51·96	30·00	51·83	30·23	51·70	30·45	51·56	30·68	60
61	52·83	30·50	52·69	30·73	52·56	30·96	52·42	31·19	61
62	53·69	31·00	53·56	31·23	53·42	31·47	53·28	31·70	62
63	54·56	31·50	54·42	31·74	54·28	31·97	54·14	32·21	63
64	55·43	32·00	55·29	32·24	55·14	32·48	55·00	32·72	64
65	56·29	32·50	56·15	32·75	56·01	32·99	55·86	33·23	65
66	57·16	33·00	57·01	33·25	56·87	33·50	56·72	33·75	66
67	58·02	33·50	57·88	33·75	57·73	34·01	57·58	34·26	67
68	58·89	34·00	58·74	34·26	58·59	34·51	58·44	34·77	68
69	59·76	34·50	59·60	34·76	59·45	35·02	59·30	35·28	69
70	60·62	35·00	60·47	35·26	60·31	35·53	60·16	35·79	70
71	61·49	35·50	61·33	35·77	61·18	36·04	61·02	36·30	71
72	62·35	36·00	62·20	36·27	62·04	36·54	61·88	36·81	72
73	63·22	36·50	63·06	36·78	62·90	37·05	62·74	37·32	73
74	64·09	37·00	63·92	37·28	63·76	37·56	63·60	37·84	74
75	64·95	37·50	64·79	37·78	64·62	38·07	64·46	38·35	75
76	65·82	38·00	65·65	38·29	65·48	38·57	65·31	38·86	76
77	66·68	38·50	66·52	38·79	66·35	39·08	66·17	39·37	77
78	67·55	39·00	67·38	39·29	67·21	39·59	67·03	39·88	78
79	68·42	39·50	68·24	39·80	68·07	40·10	67·89	40·39	79
80	69·28	40·00	69·11	40·30	68·93	40·60	68·75	40·90	80
81	70·15	40·50	69·97	40·81	69·79	41·11	69·61	41·41	81
82	71·01	41·00	70·83	41·31	70·65	41·62	70·47	41·93	82
83	71·88	41·50	71·70	41·81	71·52	42·13	71·33	42·44	83
84	72·75	42·00	72·56	42·32	72·38	42·63	72·19	42·95	84
85	73·61	42·50	73·43	42·82	73·24	43·14	73·05	43·46	85
86	74·48	43·00	74·29	43·32	74·10	43·65	73·91	43·97	86
87	75·34	43·50	75·15	43·83	74·96	44·16	74·77	44·48	87
88	76·21	44·00	76·02	44·33	75·82	44·66	75·63	44·99	88
89	77·08	44·50	76·88	44·84	76·68	45·17	76·49	45·51	89
90	77·94	45·00	77·75	45·34	77·55	45·68	77·35	46·02	90
91	78·81	45·50	78·61	45·84	78·41	46·19	78·21	46·53	91
92	79·67	46·00	79·47	46·35	79·27	46·69	79·07	47·04	92
93	80·54	46·50	80·34	46·85	80·13	47·20	79·92	47·55	93
94	81·41	47·00	81·20	47·35	80·99	47·71	80·78	48·06	94
95	82·27	47·50	82·06	47·86	81·85	48·22	81·64	48·57	95
96	83·14	48·00	82·93	48·36	82·72	48·72	82·50	49·08	96
97	84·00	48·50	83·79	48·87	83·58	49·23	83·36	49·60	97
98	84·87	49·00	84·66	49·37	84·44	49·74	84·22	50·11	98
99	85·74	49·50	85·52	49·87	85·30	50·25	85·08	50·62	99
100	86·60	50·00	86·38	50·38	86·16	50·75	85·94	51·13	100
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
					59½ Deg.		59¼ Deg.		

Distance.	31 Deg.		31¼ Deg.		31½ Deg.		31¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·86	0·51	0·85	0·52	0·85	0·52	0·85	0·53	1
2	1·71	1·03	1·71	1·04	1·71	1·04	1·70	1·05	2
3	2·57	1·55	2·56	1·56	2·56	1·57	2·55	1·58	3
4	3·43	2·06	3·42	2·08	3·41	2·09	3·40	2·10	4
5	4·29	2·58	4·27	2·59	4·26	2·61	4·25	2·63	5
6	5·14	3·09	5·13	3·11	5·12	3·13	5·10	3 16	6
7	6·00	3·61	5·98	3·63	5·97	3·66	5·95	3·68	7
8	6·86	4·12	6·84	4·15	6·82	4·18	6·80	4·21	8
9	7·71	4·64	7·69	4·67	7·67	4·70	7·65	4·74	9
10	8·57	5·15	8·55	5·19	8·53	5·22	8·50	5·26	10
11	9·43	5·67	9·40	5·71	9·38	5·75	9·35	5·79	11
12	10·29	6·18	10 26	6·23	10·23	6·27	10·20	6·31	12
13	11·14	6·70	11·11	6·74	11·08	6·79	11·05	6·84	13
14	12·00	7·21	11·97	7·26	11·94	7·31	11·90	7·37	14
15	12·86	7·73	12·82	7·78	12·79	7·84	12·76	7·89	15
16	13·71	8·24	13·68	8·30	13·64	8·36	13·61	8·42	16
17	14·57	8·76	14·53	8·82	14·49	8·88	14·46	8·95	17
18	15·43	9·27	15·39	9·34	15·35	9·40	15·31	9·47	18
19	16·29	9·79	16·24	9·86	16·20	9·93	16·16	10·00	19
20	17·14	10·30	17·10	10·38	17·05	10·45	17·01	10·52	20
21	18·00	10·82	17·95	10·89	17·91	10·97	17·86	11·05	21
22	18·86	11·33	18·81	11·41	18·76	11·49	18·71	11·58	22
23	19·71	11·85	19·66	11·93	19·61	12·02	19·56	12·10	23
24	20·57	12·36	20·52	12·45	20·46	12·54	20·41	12·63	24
25	21·43	12·88	21·37	12·97	21·32	13·06	21·26	13·16	25
26	22·29	13·39	22·23	13·49	22·17	13·58	22·11	13·68	26
27	23·14	13·91	23·08	14·01	23·02	14·11	22·96	14·21	27
28	24·00	14·42	23·94	14·53	23·87	14·63	23·81	14·73	28
29	24·86	14·94	24·79	15·04	24·73	15·15	24·66	15·26	29
30	25·71	15·45	25·65	15·56	25·58	15·67	25·51	15·79	30
31	26·57	15·97	26·50	16·08	26·43	16·20	26·36	16·31	31
32	27·43	16·48	27·36	16·60	27·28	16·72	27·21	16·84	32
33	28·29	17·00	28·21	17·12	28·14	17.24	28·06	17·37	33
34	29·14	17·51	29·07	17·64	28·99	17·76	28·91	17·89	34
35	30·00	18·03	29·92	18·16	29·84	18·29	29·76	18·42	35
36	30·86	18·54	30·78	18·68	30·70	18·81	30·61	18·94	36
37	31·72	19·06	31·63	19·19	31·55	19·33	31·46	19·47	37
38	32·57	19·57	32·49	19·71	32·40	19·85	32·31	20·00	38
39	33·43	20·09	33·34	20·23	33·25	20·38	33·16	20·52	39
40	34·29	20·60	34·20	20·75	34·11	20·90	34·01	21·05	40
41	35·14	21·12	35·05	21·27	34·96	21·42	34·86	21·57	41
42	36·00	21·63	35·91	21·79	35·81	21·94	35·71	22·10	42
43	36·86	22·15	36·76	22·31	36·66	22·47	36·57	22·63	43
44	37·72	22·66	37·62	22·83	37·52	22·99	37·42	23·15	44
45	38·57	23·18	38·47	23·34	38·37	23·51	38·27	23·68	45
46	39·43	23·69	39·33	23·86	39·22	24·03	39·12	24·21	46
47	40·29	24·21	40·18	24·38	40·07	24·56	39·97	24·73	47
48	41·14	24·72	41·04	24·90	40·93	25·08	40·82	25·26	48
49	42·00	25·24	41·89	25·42	41·78	25·60	41·67	25·78	49
50	42·86	25·75	42·75	25·94	42·63	26·12	42·52	26·31	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	59 Deg.		58¾ Deg.		58½ Deg.		58¼ Deg.		

Distance.	31 Deg.		31¼ Deg.		31½ Deg.		31¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	43·72	26·27	43·60	26·46	43·48	26·65	43·37	26·84	51
52	44·57	26·78	44·46	26·98	44·34	27·17	44·22	27·36	52
53	45·43	27·30	45·31	27·49	45·19	27·69	45·07	27·89	53
54	46·29	27·81	46·17	28·01	46·04	28·21	45·92	28·42	54
55	47·14	28·33	47·02	28·53	46·90	28·74	46·77	28·94	55
56	48·00	28·84	47·88	29·05	47·75	29·26	47·62	29·47	56
57	48·86	29·36	48·73	29·57	48·60	29·78	48·47	29·99	57
58	49·72	29·87	49·58	30·09	49·45	30·30	49·32	30·52	58
59	50·57	30·39	50·44	30·61	50·31	30·83	50·17	31·05	59
60	51·43	30·90	51·29	31·13	51·16	31·35	51·02	31·57	60
61	52·29	31·42	52·15	31·65	52·01	31·87	51·87	32·10	61
62	53·14	31·93	53·00	32·16	52·86	32·39	52·72	32·63	62
63	54·00	32·45	53·86	32·68	53·72	32·92	53·57	33·15	63
64	54·86	32·96	54·71	33·20	54·57	33·44	54·42	33·68	64
65	55·72	33·48	55·57	33·72	55·42	33·96	55·27	34·20	65
66	56·57	33·99	56·42	34·24	56·27	34·48	56·12	34·73	66
67	57·43	34·51	57·28	34·76	57·13	35·01	56·98	35·26	67
68	58·29	35·02	58·13	35·28	57·98	35·53	57·82	35·78	68
69	59·14	35·54	58·99	35·80	58·83	36·05	58·67	36·31	69
70	60·00	36·05	59·84	36·31	59·68	36·57	59·52	36·83	70
71	60·86	36·57	60·70	36·83	60·54	37·10	60·37	37·36	71
72	61·72	37·08	61·55	37·35	61·39	37·62	61·23	37·89	72
73	62·57	37·60	62·41	37.87	62·24	38·14	62·08	38·41	73
74	63·43	38·11	63·26	38·39	63·10	38·66	62·93	38·94	74
75	64·29	38·63	64·12	38·91	63·95	39·19	63·78	39·47	75
76	65·14	39·14	64·97	39·43	64·80	39·71	64·63	39·99	76
77	66·00	39·66	65·83	39·95	65·65	40·23	65·48	40·52	77
78	66·86	40·17	66·68	40·46	66·51	40·75	66·33	41·04	78
79	67·72	40·69	67·54	40·98	67·36	41·28	67·18	41·57	79
80	68·57	41·20	68·39	41·50	68·21	41·80	68·03	42·10	80
81	69·43	41·72	69·25	42·02	69·06	42·32	68·88	42·62	81
82	70·29	42·23	70·10	42·54	69·92	42·84	69·73	43·15	82
83	71·14	42·75	70·96	43·06	70·77	43·37	70·58	43·68	83
84	72·00	43·26	71·81	43·58	71·62	43·89	71·43	44·20	84
85	72·86	43·78	72·67	44·10	72·47	44·41	72·28	44·73	85
86	73·72	44·29	73·52	44·61	73·33	44·93	73·13	45·25	86
87	74·57	44·81	74·38	45·13	74·18	45·46	73·98	45·78	87
88	75·43	45·32	75·23	45·65	75·03	45·98	74·83	46·31	88
89	76·29	45·84	76·09	46·17	75·88	46·50	75·68	46·83	89
90	77·15	46·35	76·94	46·69	76·74	47.02	76·53	47·36	90
91	78·00	46·87	77·80	47·21	77·59	47·55	77·38	47·89	91
92	78·86	47·38	78·65	47·73	78·44	48·07	78·23	48·41	92
93	79·72	47·90	79·51	48·25	79·30	48·59	79·08	48·94	93
94	80·57	48·41	80·36	48·76	80·15	49·11	79·93	49·47	94
95	81·43	48·93	81·22	49·28	81·00	49·64	80·78	49·99	95
96	82·29	49·44	82·07	49·80	81·85	50·16	81·63	50·52	96
97	83·15	49·96	82·93	50·32	82·71	50·68	82·48	51·04	97
98	84·00	50·47	83·78	50·84	83·56	51·20	83·33	51·57	98
99	84·86	50·99	84·64	51·36	84·41	51·73	84·18	52·10	99
100	85·72	51·50	85·49	51·88	85·26	52·25	85·04	52·62	100
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
Distance.	59 Deg.		58¾ Deg.		58½ Deg.		58¼ Deg.		Distance.

Distance.	32 Deg.		32¼ Deg.		32½ Deg.		32¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat	Dep.	Lat.	Dep.	
1	0·85	0·53	0·85	0·53	0·84	0·54	0·84	0·54	1
2	1·70	1·06	1·69	1·07	1·69	1·07	1·68	1·08	2
3	2·54	1·59	2·54	1·60	2·53	1·61	2·52	1·62	3
4	3·39	2·12	3·38	2·13	3·37	2·15	3·36	2·16	4
5	4·24	2·65	4·23	2·67	4·22	2·69	4·21	2·70	5
6	5·09	3·18	5·07	3·20	5·06	3·22	5·05	3·25	6
7	5·94	3·71	5·92	3·74	5·90	3·76	5·89	3·79	7
8	6·78	4·24	6·77	4·27	6·75	4·30	6·73	4·33	8
9	7·63	4·77	7·61	4·80	7·59	4·84	7·57	4·87	9
10	8·48	5·30	8·46	5·34	8·43	5·37	8·41	5·41	10.
11	9·33	5·83	9·30	5·87	9·28	5·91	9·25	5·95	11
12	10·18	6·36	10·15	6·40	10·12	6·45	10·09	6·49	12
13	11·02	6·89	10·99	6·94	10·96	6·98	10·93	7·03	13
14	11·87	7·42	11·84	7·47	11·81	7·52	11·77	7 57	14
15	12·72	7·95	12·69	8·00	12·65	8·06	12·62	8·11	15
16	13·57	8·48	13·53	8·54	13·49	8·60	13·46	8·66	16
17	14·42	9·01	14·38	9·07	14·34	9·13	14·30	9·20	17
18	15·26	9·54	15·22	9·61	15·18	9·67	15·14	9·74	18
19	16·11	10·07	16·07	10·14	16·02	10·21	15·98	10·28	19
20	16·96	10·60	16·91	10·67	16·87	10·75	16·82	10·82	20
21	17·81	11·13	17·76	11·21	17·71	11·28	17·66	11·36	21
22	18·66	11·66	18·61	11·74	18·55	11·82	18·50	11·90	22
23	19·51	12·19	19·45	12·27	19·40	12·36	19·34	12·44	23
24	20·35	12·72	20·30	12·81	20·24	12·90	20·18	12·98	24
25	21·20	13·25	21·14	13·34	21·08	13·43	21·03	13·52	25
26	22·05	13·78	21·99	13·87	21·93	13·97	21·87	14·07	26
27	22·90	14·31	22·83	14·41	22·77	14·51	22.71	14·61	27
28	23·75	14·84	23·68	14·94	23·61	15·04	23·55	15·15	28
29	24·59	15·37	24·53	15·47	24·46	15·58	24·39	15·69	29
30	25·44	15·90	25·37	16·01	25·30	16·12	25·23	16·23	30
31	26·29	16·43	26·22	16·54	26·15	16·66	26·07	16·77	31
32	27·14	16·96	27·06	17·08	26·99	17·19	26·91	17·31	32
33	27·99	17·49	27·91	17·61	27·83	17·73	27·75	17·85	33
34	28·83	18·02	28·75	18·14	28·68	18·27	28·60	18·39	34
35	29·68	18·55	29·60	18·68	29·52	18·81	29·44	18·93	35
36	30·53	19·08	30·45	19·21	30·36	19·34	30·28	19·48	36
37	31·38	19·61	31·29	19·74	31·21	19·88	31·12	20·02	37
38	32·23	20·14	32·14	20·28	32·05	20·42	31·96	20·56	38
39	33·07	20·67	32·98	20·81	32·89	20·95	32·80	21·10	39
40	33·92	21·20	33·83	21·34	33·74	21·49	33·64	21·64	40
41	34·77	21·73	34·67	21·88	34·58	22·03	34·48	22·18	41
42	35·62	22·26	35·52	22·41	35·42	22·57	35·32	22·72	42
43	36·47	22·79	36·37	22·95	36·27	23·10	36·16	23·20	43
44	37·31	23·32	37·21	23·48	37·11	23·64	37·01	23·80	44
45	38·16	23·85	38·06	24·01	37·95	24·18	37·85	24·34	45
46	39·01	24·38	38·90	24·55	38·80	24·72	38·69	24·88	46
47	39·86	24·91	39·75	25·08	39·64	25·25	39·53	25·43	47
48	40·71	25·44	40·59	25·61	40·48	25·79	40·37	25·97	48
49	41·55	25·97	41·44	26·15	41·33	26·33	41·21	26·51	49
50	42·40	26·50	42·29	26·68	42·17	26·86	42·05	27·05	50
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
Distance.	58 Deg.		57¾ Deg.		57½ Deg.		57¼ Deg.		Distance.

Distance.	32 Deg.		32¼ Deg.		32½ Deg.		32¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	43·25	27·03	43·13	27·21	43·01	27·40	42·89	27·59	51
52	44·10	27·56	43·98	27·75	43·86	27·94	43·73	28·13	52
53	44·95	28·09	44·82	28·28	44·70	28·48	44·58	28·67	53
54	45·79	28·62	45·67	28·82	45·54	29·01	45·42	29·21	54
55	46·64	29·15	46·51	29·35	46·39	29·55	46·26	29·75	55
56	47·49	29·68	47·36	29·88	47·23	30·09	47·10	30·29	56
57	48·34	30·21	48·21	30·42	48·07	30·63	47·94	30·84	57
58	49·19	30·74	49·05	30·95	48·92	31·16	48·78	31·38	58
59	50·03	31·27	49·90	31·48	49·76	31·70	49·62	31·92	59
60	50·88	31·80	50·74	32·02	50·60	32·24	50·46	32·46	60
61	51·73	32·33	51·59	32·55	51·45	32·78	51·30	33·00	61
62	52·58	32·85	52·44	33·08	52·29	33·31	52·14	33·54	62
63	53·43	33·38	53·28	33·62	53·13	33·85	52·99	34·08	63
64	54·28	33·91	54·13	34·15	53·98	34·39	53·83	34·62	64
65	55·12	34·44	54·97	34·68	54·82	34·92	54·67	35·16	65
66	55·97	34·97	55·82	35·22	55·66	35·46	55·51	35·70	66
67	56·82	35·50	56·66	35·75	56·51	36·00	56·35	36·25	67
68	57·67	36·03	57·51	36·29	57·35	36·54	57·19	36·79	68
69	58·52	36·56	58·36	36·82	58·19	37·07	58·03	37·33	69
70	59·36	37·09	59·20	37·35	59·04	37·61	58·87	37·87	70
71	60·21	37·62	60·05	37·89	59·88	38·15	59·71	38·41	71
72	61·06	38·15	60·89	38·42	60·72	38·69	60·55	38·95	72
73	61·91	38·68	61·74	38·95	61·57	39·22	61·40	39·49	73
74	62·76	39·21	62·58	39·49	62·41	39·76	62·24	40·03	74
75	63·60	39·74	63·43	40·02	63·25	40·30	63·08	40·67	75
76	64·45	40·27	64·28	40·55	64·10	40·83	63·92	41·11	76
77	65·30	40·80	65·12	41·09	64·94	41·37	64·76	41·65	77
78	66·15	41·33	65·97	41·62	65·78	41·91	65·60	42·20	78
79	67·00	41·86	66·81	42·16	66·63	42·45	66·44	42·74	79
80	67·84	42·39	67·66	42·69	67·47	42·98	67·28	43·28	80
81	68·69	42·92	68·50	43·22	68·31	43·52	68·12	43·82	81
82	69·54	43·45	69·35	43·76	69·16	44·06	68·97	44·36	82
83	70·39	43·98	70·20	44·29	70·00	44·60	69·81	44·90	83
84	71·24	44·51	71·04	44·82	70·84	45·13	70·65	45·44	84
85	72·08	45·04	71·89	45·36	71·69	45·67	71·49	45·98	85
86	72·93	45·57	72·73	45·89	72·53	46·21	72·33	46·52	86
87	73·78	46·10	73·58	46·42	73·38	46·75	73·17	47·06	87
88	74·63	46·63	74·42	46·96	74·22	47.28	74·01	47·61	88
89	75·48	47·16	75·27	47·49	75·06	47·82	74·85	48·15	89
90	76·32	47·69	76·12	48·03	75·91	48·36	75·69	48·69	90
91	77·17	48·22	76·96	48·56	76·75	48·89	76·53	49·23	91
92	78·02	48·75	77·81	49·09	77·59	49·43	77·38	49·77	92
93	78·87	49·28	78·65	49·63	78·44	49·97	78·22	50·31	93
94	79·72	49·81	79·50	50·16	79·28	50·51	79·06	50·85	94
95	80·56	50·34	80·34	50·69	80·12	51·04	79·90	51·39	95
96	81·41	50·87	81·19	51·23	80·97	51·58	80·74	51·93	96
97	82·26	51·40	82·04	51·76	81·81	52·12	81·58	52·47	97
98	83·11	51·93	82·88	52·29	82·65	52·66	82·42	53·02	98
99	83·96	52·46	83·73	52·83	83·50	53·19	83·26	53·56	99
100	84·80	52·99	84·57	53·36	84·34	53·73	84·10	54·10	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	58 Deg.		57¾ Deg.		57½ Deg.		57¼ Deg.		

Distance.	33 Deg.		33¼ Deg.		33½ Deg.		33¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·84	0·54	0·84	0·55	0·83	0·55	0·83	0·56	1
2	1·68	1·09	1·67	1·10	1·67	1·10	1·66	1·11	2
3	2·52	1·63	2·51	1·64	2·50	1·66	2·49	1·67	3
4	3·35	2·18	3·35	2·19	3·34	2·21	3·33	2·22	4
5	4·19	2·72	4·18	2·74	4·17	2·76	4·16	2·78	5
6	5·03	3·27	5·02	3·29	5·00	3·31	4·99	3·33	6
7	5·87	3·81	5·85	3·84	5·84	3·86	5·82	3·89	7
8	6·71	4·36	6·69	4·39	6·67	4·42	6·65	4·44	8
9	7·55	4·90	7·53	4·93	7·50	4·97	7·48	5·00	9
10	8·39	5·45	8·36	5.48	8·34	5·52	8·31	5·56	10
11	9·23	5·99	9·20	6·03	9·17	6·07	9·15	6·11	11
12	10·06	6·54	10·04	6·58	10·01	6·62	9·98	6·67	12
13	10·90	7·08	10·87	7·13	10·84	7·18	10·81	7·22	13
14	11·74	7·62	11·71	7·68	11·67	7·73	11·64	7·78	14
15	12·58	8·17	12·54	8·22	12·51	8·28	12·47	8·33	15
16	13·42	8·71	13·38	8·77	13·34	8·83	13·30	8·89	16
17	14·26	9·26	14·22	9·32	14·18	9·38	14·13	9·44	17
18	15·10	9·80	15·05	9·87	15·01	9·93	14·97	10·00	18
19	15·93	10·35	15·89	10.42	15·84	10·49	15·80	10·56	19
20	16·77	10·89	16·73	10·97	16·68	11·04	16·63	11·11	20
21	17·61	11·44	17·56	11·51	17·51	11·59	17·46	11·67	21
22	18·45	11·98	18·40	12·06	18·35	12.14	18·29	12·22	22
23	19·29	12·53	19·23	12·61	19·18	12·69	19·12	12·78	23
24	20·13	13·07	20·07	13·16	20·01	13·25	19·96	13·33	24
25	20·97	13·62	20·91	13·71	20·85	13·80	20·79	13·89	25
26	21·81	14·16	21·74	14·26	21·68	14·35	21·62	14·44	26
27	22·64	14·71	22·58	14·80	22·51	14·90	22·45	15·00	27
28	23·48	15·25	23·42	15.35	23·35	15·45	23·28	15·56	28
29	24·32	15·79	24·25	15·90	24·18	16·01	24·11	16·11	29
30	25·16	16·34	25·09	16·45	25·02	16·56	24·94	16·67	30
31	26·00	16·88	25·92	17·00	25·85	17·11	25·78	17·22	31
32	26·84	17·43	26·76	17·55	26·68	17·66	26·61	17·78	32
33	27·68	17·97	27·60	18·09	27·52	18·21	27·44	18·33	33
34	28·51	18·52	28·43	18·64	28·35	18·77	28·27	18·89	34
35	29·35	19·06	29·27	19·19	29·19	19·32	29·10	19·44	35
36	30·19	19·61	30·11	19·74	30·02	19·87	29·93	20·00	36
37	31·03	20·15	30·94	20·29	30·85	20·42	30·76	20·56	37
38	31·87	20·70	31·78	20·84	31·69	20·97	31·60	21·11	38
39	32·71	21·24	32·62	21·38	32·52	21·53	32·43	21·67	39
40	33·55	21·79	33·45	21·93	33·36	22·08	33·26	22·22	40
41	34·39	22·33	34·29	22·48	34·19	22·63	34·09	22·78	41
42	35·22	22·87	35·12	23·03	35·02	23·18	34·92	23·33	42
43	36·06	23·42	35·96	23·58	35·86	23·73	35·75	23·89	43
44	36·90	23·96	36·80	24·12	36·69	24·29	36·58	24·45	44
45	37·74	24·51	37·63	24·67	37·52	24·84	37·42	25·00	45
46	38·58	25·05	38·47	25·22	38·36	25·39	38·25	25·56	46
47	39·42	25·60	39·31	25·77	39·19	25·94	39·08	26·11	47
48	40·26	26·14	40·14	26·32	40·03	26·49	39·91	26·67	48
49	41·09	26·69	40·98	26·87	40·86	27·04	40·74	27·22	49
50	41·93	27·23	41·81	27·41	41·69	27·60	41·57	27·78	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	57 Deg.		56¾ Deg.		56½ Deg.		56¼ Deg.		

Distance.	33 Deg.		33¼ Deg.		33½ Deg.		33¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	42·77	27·78	42·65	27·96	42·53	28·15	42·40	28·33	51
52	43·61	28·32	43·49	28·51	43·36	28·70	43·24	28·89	52
53	44·45	28·87	44·32	29·06	44·20	29·25	44·07	29·45	53
54	45·29	29·41	45·16	29·61	45·03	29·80	44·90	30·00	54
55	46·13	29·96	46·00	30·16	45·86	30·36	45·73	30·56	55
56	46·97	30·50	46·83	30·70	46·70	30·91	46·56	31·11	56
57	47·80	31·04	47·67	31·25	47·53	31·46	47·39	31·67	57
58	48·64	31·59	48·50	31·80	48·37	32·01	48·23	32·22	58
59	49·48	32·13	49·34	32·35	49·20	32·56	49·06	32·78	59
60	50·32	32·68	50·18	32·90	50·03	33·12	49·89	33·33	60
61	51·16	33·22	51·01	33·45	50·87	33·67	50·72	33·89	61
62	52·00	33·77	51·85	33·99	51·70	34·22	51·55	34·45	62
63	52·84	34·31	52·69	34·54	52·53	34·77	52·38	35·00	63
64	53·67	34·86	53·52	35·09	53·37	35·32	53·21	35·56	64
65	54·51	35·40	54·36	35·64	54·20	35·88	54·05	36·11	65
66	55·35	35·95	55·19	36·19	55·04	36·43	54·88	36·67	66
67	56·19	36·49	56·03	36·74	55·87	36·98	55·71	37·22	67
68	57·03	37·04	56·87	37·28	56·70	37·53	56·54	37·78	68
69	57·87	37·58	57·70	37·83	57·54	38·08	57·37	38·33	69
70	58·71	38·12	58·54	38·38	58·37	38·64	58·20	38·89	70
71	59·55	38·67	59·38	38·93	59·21	39·19	59·03	39·45	71
72	60·38	39·21	60·21	39·48	60·04	39·74	59·87	40·00	72
73	61·22	39·76	61·05	40·03	60·87	40·29	60·70	40·56	73
74	62·06	40·30	61·89	40·57	61·71	40·84	61·53	41·11	74
75	62·90	40·85	62·72	41·12	62·54	41·40	62·36	41·67	75
76	63·74	41·39	63·56	41·67	63·38	41·95	63·19	42·22	76
77	64·58	41·94	64·39	42·22	64·21	42·50	64·02	42·78	77
78	65·42	42·48	65·23	42·77	65·04	43·05	64·85	43·33	78
79	66·25	43·03	66·07	43·32	65·88	43·60	65·69	43·89	79
80	67·09	43·57	66·90	43·86	66·71	44·15	66·52	44·45	80
81	67·93	44·12	67·74	44·41	67·54	44·71	67·35	45·00	81
82	68·77	44·66	68·58	44 96	68·28	45·26	68·18	45·56	82
83	69·61	45·20	69·41	45·51	69·21	45·81	69·01	46·11	83
84	70·45	45·75	70·25	46·06	70·05	46·36	69·84	46·67	84
85	71·29	46·29	71·08	46·60	70·88	46·91	70·67	47·22	85
86	72·13	46·84	71·92	47·15	71·71	47·47	71·51	47·78	86
87	72·96	47·38	72·76	47·70	72·55	48·02	72·34	48·33	87
88	73·80	47·93	73·59	48·25	73·38	48·57	73·17	48·89	88
89	74·64	48·47	74·43	48·80	74·22	49·12	74·00	49·45	89
90	75·48	49·02	75·27	49·35	75·05	49·67	74·83	50·00	90
91	76·32	49·56	76·10	49·89	75·88	50·23	75·66	50·56	91
92	77·16	50·11	76·94	50·44	76·72	50·78	76·50	51·11	92
93	78·00	50·65	77·77	50·99	77·55	51·33	77·33	51·67	93
94	78·83	51·20	78·61	51·54	78·39	51·88	78·16	52·22	94
95	79·67	51·74	79·45	52·09	79·22	52·43	78·99	52·78	95
96	80·51	52·29	80·28	52·64	80·05	52·99	79·82	53·33	96
97	81·35	52·83	81·12	53·18	80·89	53·54	80·65	53·89	97
98	82·19	53·37	81·96	53·73	81·72	54·09	81·48	54·45	98
99	83·03	53·92	82·79	54·28	82·55	54·64	82·32	55·00	99
100	83·87	54·46	83·63	54·83	83·39	55·19	83·15	55·56	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	57 Deg.		56¾ Deg.		56½ Deg.		56¼ Deg.		

Distance.	34 Deg.		34¼ Deg.		34½ Deg.		34¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·83	0·56	0·83	0·56	0·82	0·57	0·82	0·57	1
2	1·66	1·12	1·65	1·13	1·65	1·13	1·64	1·14	2
3	2·49	1·68	2·48	1·69	2·47	1·70	2·46	1·71	3
4	3·32	2·24	3·31	2·25	3·30	2·27	3·29	2·28	4
5	4·15	2·80	4·13	2·81	4·12	2·83	4·11	2·85	5
6	4·97	3·36	4·96	3·38	4·94	3·40	4·93	3·42	6
7	5·80	3·91	5·79	3·94	5·77	3·99	5·75	3·99	7
8	6·63	4·47	6·61	4·50	6·59	4·53	6·57	4·56	8
9	7·46	5·03	7·44	5·07	7·42	5·10	7·39	5·13	9
10	8·29	5·59	8·27	5·63	8·24	5·66	8·22	5·70	10
11	9·12	6·15	9·09	6·19	9·07	6·23	9·04	6·27	11
12	9·95	6·71	9·92	6·75	9·89	6·80	9·86	6·84	12
13	10·78	7·27	10·75	7·32	10·71	7·36	10·68	7·41	13
14	11·61	7·83	11·57	7·88	11·54	7·93	11·50	7·98	14
15	12·44	8·39	12·40	8·44	12·36	8·50	12·32	8·55	15
16	13·26	8·95	13·23	9·00	13·19	9·06	13·15	9·12	16
17	14·09	9·51	14·05	9·57	14·01	9·63	13·97	9·69	17
18	14·92	10·07	14·88	10·13	14·83	10·20	14·79	10·26	18
19	15·75	10·62	15·71	10·69	15·66	10·76	15·61	10·83	19
20	16·58	11·18	16·53	11·26	16·48	11·33	16·43	11·40	20
21	17·41	11·74	17·36	11·82	17·31	11·89	17·25	11·97	21
22	18·24	12·30	18·18	12·38	18·13	12·46	18·08	12·54	22
23	19·07	12·86	19·01	12·94	18·95	13·03	18·90	13·11	23
24	19·90	13·42	19·84	13·51	19·78	13·59	19·72	13·68	24
25	20·73	13·98	20·66	14·07	20·60	14·16	20·54	14·25	25
26	21·55	14·54	21·49	14·63	21·43	14·73	21·36	14·82	26
27	22·38	15·10	22·32	15·20	22·25	15·29	22·18	15·39	27
28	23·21	15·66	23·14	15·76	23·08	15·86	23·01	15·96	28
29	24·04	16·22	23·97	16·32	23·90	16·44	23·83	16·53	29
30	24·87	16·78	24·80	16·88	24·72	16·99	24·65	17·10	30
31	25·70	17·33	25·62	17·45	25·55	17·56	25·47	17·67	31
32	26·53	17·89	26·45	18.01	26·37	18·12	26·29	18·24	32
33	27·36	18·45	27·28	18·57	27·20	18·69	27·11	18·81	33
34	28·19	19·01	28·10	19·14	28·02	19·26	27·94	19·38	34
35	29·02	19·57	28·93	19·70	28·84	19·82	28·76	19·95	35
36	29·85	20·13	29·76	20·26	29·67	20·39	29·58	20·52	36
37	30·67	20·69	30·58	20·82	30·49	20·96	30·40	21·09	37
38	31·50	21·25	31·41	21·39	31·32	21·52	31·22	21·66	38
39	32·33	21·81	32·24	21·95	32·14	22·09	32·04	22·23	39
40	33·16	22·37	33·06	22·51	32·97	22·66	32·87	22·80	40
41	33·99	22·93	33·89	23·07	33·79	23·22	33·69	23·37	41
42	34·82	23·49	34·72	23·64	34·61	23·79	34·51	23·94	42
43	35·65	24·05	35·54	24·20	35·44	24·36	35·33	24·51	43
44	36·48	24·60	36·37	24·76	36·26	24·92	36·15	25·08	44
45	37·31	25·16	37·20	25·33	37·09	25·49	36·97	25·65	45
46	38·14	25·72	38·02	25·89	37·91	26·05	37·80	26·22	46
47	38·96	26·28	38·85	26·45	38·73	26·62	38·62	26·79	47
48	39·79	26·84	39·68	27·01	39·56	27·19	39·44	27·36	48
49	40·62	27·40	40·50	27·58	40·38	27·75	40·26	27·93	49
50	41·45	27·96	41·33	28·14	41·21	28·32	41·08	28·50	50
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
Distance.	56 Deg.		55¾ Deg.		55½ Deg.		55¼ Deg.		Distance.

Distance.	34 Deg. Lat.	34 Deg. Dep.	34¼ Deg. Lat.	34¼ Deg. Dep.	34½ Deg. Lat.	34½ Deg. Dep.	34¾ Deg. Lat.	34¾ Deg. Dep.	Distance.
51	42·28	28·52	42·16	28·70	42·03	28·89	41·90	29·07	51
52	43·11	29·08	42·98	29·27	42·85	29·45	42·73	29·64	52
53	43·94	29·64	43·81	29·83	43·68	30·02	43·55	30·21	53
54	44·77	30·20	44·64	30·39	44·50	30·59	44·37	30·78	54
55	45·60	30·76	45·46	30·95	45·33	31·15	45·19	31·35	55
56	46·43	31·31	46·29	31·52	46·15	31·72	46·01	31·92	56
57	47·26	31·87	47·12	32·08	46·98	32·29	46·83	32·49	57
58	48·08	32·43	47·94	32·64	47·80	32·85	47·66	33·06	58
59	48·91	32·99	48·77	33·21	48·62	33·42	48·48	33·63	59
60	49·74	33·55	49·60	33·77	49·45	33·98	49·30	34·20	60
61	50·57	34·11	50·42	34·33	50·27	34·55	50·12	34·77	61
62	51·40	34·67	51·25	34·89	51·10	35·12	50·94	35·34	62
63	52·23	35·23	52·08	35·46	51·92	35·68	51·76	35·91	63
64	53·06	35·79	52·90	36·02	52·74	36·25	52·59	36·48	64
65	53·89	36·35	53·73	36·58	53·57	36·82	53·41	37·05	65
66	54·72	36·91	54·55	37·15	54·39	37·38	54·23	37·62	66
67	55·55	37·46	55·38	37·71	55·22	37·95	55·05	38·19	67
68	56·37	38·03	56·21	38·27	56·04	38·52	55·87	38·76	68
69	57·20	38·58	57·03	38·83	56·86	39·08	56·69	39·33	69
70	58·03	39·14	57·86	39·40	57·69	39·65	57·52	39·90	70
71	58·86	39·70	58·69	39·96	58·51	40·21	58·34	40·47	71
72	59·69	40·26	59·51	40·52	59·34	40·78	59·16	41·04	72
73	60·52	40·82	60·34	41·08	60·16	41·35	59·98	41·61	73
74	61·35	41·38	61·17	41·65	60·99	41·91	60·80	42·18	74
75	62·18	41·94	61·99	42·21	61·81	42·48	61·62	42.75	75
76	63·01	42·50	62·82	42·77	62·63	43·05	62·45	43·32	76
77	63·84	43·06	63·65	43·34	63·46	43·61	63·27	43·89	77
78	64·66	43·62	64·47	43·90	64·28	44·18	64·09	44·46	78
79	65·49	44·18	65·30	44·46	65·11	44·75	64·91	45·03	79
80	66·32	44·74	66·13	45·02	65·93	45·31	65·73	45·60	80
81	67·15	45·29	66·95	45·59	66·75	45·88	66·55	46·17	81
82	67·98	45·85	67·78	46·15	67·58	46·45	67·37	46.74	82
83	68·81	46·41	68·61	46·71	68·40	47·01	68·20	47·31	83
84	69·64	46·97	69·43	47·28	69·23	47·58	69·02	47·88	84
85	70·47	47·53	70·26	47·84	70·05	48·14	69·84	48·45	85
86	71·30	48·09	71·09	48·40	70·87	48·71	70·66	49·02	86
87	72·13	48·65	71·91	48·96	71·70	49·28	71·48	49·59	87
88	72·96	49·21	72·74	49·53	72·52	49·84	72·30	50·16	88
89	73·78	49·77	73·57	50·09	73·35	50·41	73·13	50·73	89
90	74·61	50·33	74·39	50·65	74·17	50·98	73·95	51·30	90
91	75·44	50·89	75·22	51·22	75·00	51·54	74·77	51·87	91
92	76·27	51·45	76·05	51·78	75·82	52·11	75·59	52·44	92
93	77·10	52·00	76·87	52·34	76·64	52·68	76·41	53·01	93
94	77·93	52·56	77·70	52·90	77·47	53·24	77·23	53·58	94
95	78·76	53·12	78·53	53·47	78·29	53·81	78·06	54·15	95
96	79·59	53·68	79·35	54·03	79·12	54·37	78·88	54·72	96
97	80·42	54·24	80·18	54·59	79·94	54·94	79·70	55·29	97
98	81·25	54·80	81·01	55·15	80·76	55·51	80·52	55·86	98
99	82·07	55·36	81·83	55·72	81·59	56·07	81·34	56·43	99
100	82·90	55·92	82·66	56·28	82·41	56·64	82·16	57·00	100
Distance.	56 Deg. Dep.	56 Deg. Lat.	55¾ Deg. Dep.	55¾ Deg. Lat.	55½ Deg. Dep.	55½ Deg. Lat.	55¼ Deg. Dep.	55¼ Deg. Lat.	Distance.

Distance.	35 Deg.		35¼ Deg.		35½ Deg.		35¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·82	0·57	0·82	0·58	0·81	0·58	0·81	0·58	1
2	1·64	1·15	1·63	1·15	1·63	1·16	1·62	1·17	2
3	2·46	1·72	2·45	1·73	2·44	1·74	2·43	1.75	3
4	3·28	2·29	3·27	2·31	3·26	2.32	3·25	2·34	4
5	4·10	2·87	4·08	2·89	4·07	2·90	4·06	2·92	5
6	4·91	3·44	4·90	3·46	4·88	3·48	4·87	3·51	6
7	5·73	4·01	5·72	4·04	5·70	4·06	5·68	4·09	7
8	6·55	4·59	6·53	4·62	6·51	4·65	6·49	4·67	8
9	7·37	5·16	7·35	5·19	7·33	5·23	7·30	5·26	9
10	8·19	5·74	8·17	5·77	8·14	5·81	8·12	5·84	10
11	9·01	6·31	8·98	6·85	8·96	6·39	8·93	6·43	11
12	9·83	6·88	9·80	6·93	9·77	6·97	9·74	7·01	12
13	10·65	7·46	10·62	7·50	10·58	7·55	10·55	7·60	13
14	11·47	8·03	11·43	8·08	11·40	8·13	11·36	8·18	14
15	12·29	8·60	12·25	8·66	12·21	8·71	12·17	8·76	15
16	13·11	9·18	13·07	9·23	13·03	9·29	12·99	9·35	16
17	13·93	9·75	13·88	9·81	13·84	9·87	13·80	9·93	17
18	14·74	10·32	14·70	10·39	14·65	10·45	14·61	10·52	18
19	15·56	10·90	15·52	10·97	15·47	11·03	15·42	11·10	19
20	16·38	11·47	16·33	11·54	16·28	11·61	16·23	11·68	20
21	17·20	12·05	17·15	12·12	17·10	12·19	17·04	12·27	21
22	18·02	12·62	17·97	12·70	18·01	12·78	17·85	12·85	22
23	18·84	13·19	18·78	13·27	18·72	13·36	18·67	13·44	23
24	19·66	13·77	19·60	13·85	19·54	13·94	19·48	14·02	24
25	20·48	14·34	20·42	14·48	20·35	14·52	20·29	14·61	25
26	21·30	14·91	23·23	15·01	21·17	15·10	21·10	15·19	26
27	22·12	15·49	22·05	15·58	21·98	15·68	21·91	15·77	27
28	22·94	16·06	22·87	16·16	22·80	16·26	22·72	16·36	28
29	23·76	16·63	23·68	16·74	23·61	16·84	23·54	16·94	29
30	24·57	17·21	24·50	17·31	24·42	17·42	24·35	17·53	30
31	25·39	17·78	25·32	17·89	25·24	18·00	25·16	18·11	31
32	26·21	18·35	26·13	18·47	26·05	18·58	25·97	18·70	32
33	27·03	18·93	26·95	19·05	26·87	19·16	26·78	19·28	33
34	27·85	19·50	27·77	19·62	27·68	19·74	27·59	19·86	34
35	28·67	20·08	28·58	20·20	28·49	20·32	28·41	20·45	35
36	29·49	20·65	29·40	20·78	29·31	20·91	29·22	21·03	36
37	30·31	21·22	30·22	21·35	30·12	21·49	30·03	21·62	37
38	31·13	21·80	31·03	21·93	30·94	22·07	30·84	22·20	38
39	31·95	22·37	31·85	22·51	31·75	22·65	31·65	22·79	39
40	32·77	22·94	32·67	23·09	32·56	23·23	32·46	23·37	40
41	33·59	23·52	33·48	23·66	33·38	23·81	33·27	23·95	41
42	34·40	24·09	34·30	24·24	34·19	24·39	34·09	24·54	42
43	35·22	24·66	35·12	24·82	35·01	24·97	34·90	25·12	43
44	36·04	25·24	35·93	25·39	35·82	25·55	35·71	25·71	44
45	36·86	25·81	36·75	25·97	36·64	26·13	36·52	26·29	45
46	37·68	26·38	37·57	26·55	37·45	26·71	37·33	26·88	46
47	38·50	26·96	38·38	27·13	38·26	27·29	38·14	27·46	47
48	39·32	27·53	39·20	27·70	39·08	27·87	38·96	28·04	48
49	40·14	28·11	40·02	28·28	39·89	28·45	39·77	28·63	49
50	40·96	28·68	40·83	28·86	40·71	29·04	40·58	29·21	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	55 Deg.		54¾ Deg.		54½ Deg.		54¼ Deg.		

Distance.	35 Deg.		35¼ Deg.		35½ Deg.		35¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	41·78	29·25	41·65	29·43	41·52	29·62	41·39	29·80	51
52	42·60	29·83	42·47	30·01	42·33	30·20	42·20	30·38	52
53	43·42	30·40	43·28	30·59	43·15	30·78	43·01	30·97	53
54	44·23	30·97	44·10	31·17	43·96	31·36	43·82	31·55	54
55	45·05	31·55	44·92	31·74	44·78	31·94	44·64	32·13	55
56	45·87	32·12	45·73	32·32	45·59	32·52	45·45	32·72	56
57	46·69	32·69	46·55	32·90	46·40	33·10	46·26	33·30	57
58	47·51	33·27	47·37	33·47	47·22	33·68	47·07	33·89	58
59	48·33	33·84	48·18	34·05	48·03	34·26	47·88	34·47	59
60	49·15	34·41	49·00	34·63	48·85	34·84	48·69	35·05	60
61	49·97	34·99	49·82	35·21	49·66	35·42	49·51	35·64	61
62	50·79	35·56	50·63	35·78	50·48	36·00	50·32	36·22	62
63	51·61	36·14	51·45	36·36	51·29	36·58	51·13	36·81	63
64	52·43	36·71	52·27	36·94	52·10	37·16	51·94	37·39	64
65	53·24	37·28	53·08	37·51	52·92	37·75	52·75	37·98	65
66	54·06	37·86	53·90	38·09	53·73	38·33	53·56	38·56	66
67	54·88	38·43	54·71	38·67	54·55	38·91	54·38	39·14	67
68	55·70	39·00	55·53	39·25	55·36	39·49	55·19	39·73	68
69	56·52	39·58	56·35	39·82	56·17	40·07	56·00	40·31	69
70	57·34	40·15	57·16	40·40	56·99	40·65	56·81	40·90	70
71	58·16	40·72	57·98	40·98	57·80	41·23	57·62	41·48	71
72	58·98	41·30	58·80	41·55	58·62	41·81	58·43	42·07	72
73	59·80	41·87	59·61	42·13	59·43	42·39	59·24	42·65	73
74	60·62	42·44	60·43	42·71	60·24	42·97	60·06	43·23	74
75	61·44	43·02	61·25	43·29	61·06	43·55	60·87	43·82	75
76	62·26	43·59	62·06	43·86	61·87	44·13	61·68	44·40	76
77	63·07	44·17	62·88	44·44	62·69	44·71	62·49	44·99	77
78	63·89	44·74	63·70	45·02	63·50	45·29	63·30	45·57	78
79	64·71	45·31	64·51	45·59	64·32	45·88	64·11	46·16	79
80	65·53	45·89	65·33	46·17	65·13	46·46	64·93	46·74	80
81	66·35	46·46	66·15	46·75	65·94	47·04	65·74	47·32	81
82	67·17	47·03	66·96	47·33	66·76	47·62	66·55	47·91	82
83	67·99	47·61	67·78	47·90	67·57	48·20	67·36	48·49	83
84	68·81	48·18	68·60	48·48	68·39	48·78	68·17	49·08	84
85	69·63	48·75	69·41	49·06	69·20	49·36	68·98	49·66	85
86	70·45	49·33	70·23	49·63	70·01	49·94	69·80	50·25	86
87	71·27	49·90	71·05	50·21	70·83	50·52	70·61	50·83	87
88	72·09	50·47	71·86	50·79	71·64	51·10	71·42	51·41	88
89	72·90	51·05	72·68	51·37	72·46	51·68	72·23	52·00	89
90	73·72	51·62	73·50	51·94	73·27	52·26	73·04	52·58	90
91	74·54	52·20	74·31	52·52	74·08	52·84	73·85	53·17	91
92	75·36	52·77	75·13	53·10	74·90	53·42	74·56	53·75	92
93	76·18	53·34	75·95	53·67	75·71	54·01	75·48	54·34	93
94	77·00	53·92	76·76	54·25	76·53	54·59	76·29	54·92	94
95	77·82	54·49	77·58	54·83	77·34	55·17	77·10	55·50	95
96	78·64	55·06	78·40	55·41	78·16	55·75	77·91	56·09	96
97	79·46	55·64	79·21	55·98	78·97	56·33	78·72	56·67	97
98	80·28	56·21	80·03	56·56	79·78	56·91	79·53	57·26	98
99	81·10	56·78	80·85	57·14	80·60	57·49	80·35	57·84	99
100	81·92	57·36	81·66	57·71	81·41	58·07	81·16	58·42	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	55 Deg.		54¾ Deg.		54½ Deg.		54¼ Deg.		

Distance.	36 Deg.		36¼ Deg.		36½ Deg.		36¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·81	0·59	0·81	0·59	0·80	0·59	0·80	0·60	1
2	1·62	1·18	1·61	1·18	1·61	1·19	1·60	1·20	2
3	2·43	1·76	2·42	1·77	2·41	1·78	2·40	1·79	3
4	3·24	2·35	3·23	2·37	3·22	2·38	3·20	2·39	4
5	4·05	2·94	4·03	2·96	4·02	2·97	4·01	2·99	5
6	4·85	3·53	4·84	3·55	4·82	3·57	4·81	3·59	6
7	5·66	4·11	5·65	4·14	5·63	4·16	5·61	4·19	7
8	6·47	4·70	6·45	4·73	6·43	4·76	6·41	4.79	8
9	7·28	5·29	7·26	5·32	7·23	5·35	7·21	5·38	9
10	8·09	5·88	8·06	5·91	8·04	5·95	8·01	5·98	10
11	8·90	6·47	8·87	6·50	8·84	6·54	8·81	6·58	11
12	9·71	7·05	9·68	7·10	9·65	7·14	9·61	7·18	12
13	10·52	7·64	10·48	7·69	10·45	7·73	10·42	7·78	13
14	11·33	8·23	11·29	8·28	11·25	8·33	11·22	8·38	14
15	12·14	8·82	12·10	8·87	12·06	8·92	12·02	8·97	15
16	12·94	9·40	12·90	9·46	12·86	9·52	12·82	9·57	16
17	13·75	9·99	13·71	10·05	13·67	10·11	13·62	10·17	17
18	14·56	10·58	14·52	10·64	14·47	10·71	14·42	10·77	18
19	15·37	11·17	15·32	11·23	15·27	11·30	15·22	11·37	19
20	16·18	11·76	16·13	11·83	16·08	11·90	16·03	11·97	20
21	16·99	12·34	16·94	12·42	16·88	12·49	16·83	12·56	21
22	17·80	12·93	17·74	13·01	17·68	13·09	17·63	13·16	22
23	18·61	13·52	18·55	13·60	18·49	13·68	18·43	13·76	23
24	19·42	14·11	19·35	14·19	19·29	14·28	19·23	14·36	24
25	20·23	14·69	20·16	14·78	20·10	14·87	20·03	14·96	25
26	21·03	15·28	20·97	15·37	20·90	15·47	20·83	15·56	26
27	21·84	15·87	21·77	15·97	21·70	16·06	21·63	16·15	27
28	22·65	16·46	22·58	16·56	22·51	16·65	22·44	16·75	28
29	23·46	17·05	23·39	17·15	23·31	17·25	23·24	17·35	29
30	24·27	17·63	24·19	17·74	24·12	17·84	24·04	17·95	30
31	25·08	18·22	25·00	18·33	24·92	18·44	24·84	18·55	31
32	25·89	18·81	25·81	18·92	25·72	19·03	25·64	19·15	32
33	26·70	19·40	26·61	19·51	26·53	19·63	26·44	19·74	33
34	27·51	19·98	27·42	20·10	27·33	20·22	27·24	20·34	34
35	28·32	20·57	28·23	20·70	28·13	20·82	28·04	20·94	35
36	29·12	21·16	29·03	21·29	28·94	21·41	28·85	21·54	36
37	29·93	21·75	29·84	21·88	29·74	22·01	29·65	22·14	37
38	30·74	22·34	30·64	22·47	30·55	22·60	30·45	22·74	38
39	31·55	22·92	31·45	23·06	31·35	23·20	31·25	23·33	39
40	32·36	23·51	32·26	23·65	32·15	23·79	32·05	23·93	40
41	33·17	24·10	33·06	24·24	32·96	24·39	32·85	24·53	41
42	33·98	24·69	33·87	24·83	33·76	24·98	33·65	25·13	42
43	34·79	25·27	34·68	25·43	34·57	25·58	34·45	25·73	43
44	35·60	25·86	35·48	26·02	35·37	26·17	35·26	26·33	44
45	36·41	26·45	36·29	26·61	36·17	26·77	36·06	26·92	45
46	37·21	27·04	37·10	27·20	36·98	27·36	36·86	27·52	46
47	38·02	27·63	37·90	27·79	37·78	27·96	37·66	28·12	47
48	38·83	28·21	38·71	28·38	38·59	28·55	38·46	28·72	48
49	39·64	28·80	39·52	28·97	39·39	29·15	39·26	29·32	49
50	40·45	29·39	40·32	29·57	40·19	29·74	40·06	29·92	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance
	54 Deg.		53¾ Deg.		53½ Deg.		53¼ Deg.		

Distance.	36 Deg.		36¼ Deg.		36½ Deg.		36¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	41·26	29·98	41·13	30·16	41·00	30·34	40·86	30·51	51
52	42·07	30·56	41·94	30·75	41·80	30·93	41·67	31·11	52
53	42·88	31·15	42·74	31·34	42·60	31·53	42·47	31·71	53
54	43·69	31·74	43·55	31·93	43·41	32·12	43·27	32·31	54
55	44·50	32·33	44·35	32·52	44·21	32·72	44·07	32·91	55
56	45·30	32·92	45·16	33·11	45·02	33·31	44·87	33·51	56
57	46·11	33·50	45·97	33·70	45·82	33·90	45·67	34·10	57
58	46·92	34·09	46·77	34·30	46·62	34·50	46·47	34·70	58
59	47·73	34·68	47·58	34·89	47·43	35·09	47·27	35·30	59
60	48·54	35·27	48·39	35·48	48·23	35·69	48·08	35·90	60
61	49·35	35·85	49·19	36·07	49·04	36·28	48·88	36·50	61
62	50·16	36·44	50·00	36·66	49·84	36·88	49·68	37·10	62
63	50·97	37·03	50·81	37·25	50·64	37·47	50·48	37·69	63
64	51·78	37·62	51·61	37·84	51·45	38·07	51·28	38·29	64
65	52·59	38·21	52·42	38·44	52·25	38·66	52·08	38·89	65
66	53·40	38·79	53·23	39·03	53·05	39·26	52·88	39·49	66
67	54·20	39·38	54·03	39·62	53·86	39·85	53·68	40·09	67
68	55·01	39·97	54·84	40·21	54·66	40·45	54·49	40·69	68
69	55·82	40·56	55·64	40·80	55·47	41·04	55·29	41·28	69
70	56·63	41·14	56·45	41·39	56·27	41·64	56·09	41·88	70
71	57·44	41·73	57·26	41·98	57·07	42·23	56·89	42·48	71
72	58·25	42·32	58·06	42·57	57·88	42·83	57·69	43·08	72
73	59·06	42·91	58·87	43·17	58·68	43·42	58·49	43·68	73
74	59·87	43·50	59·68	43·76	59·49	44·02	59·29	44·28	74
75	60·68	44·08	60·48	44·35	60·29	44·61	60·09	44·87	75
76	61·49	44·67	61·29	44·94	61·09	45·21	60·90	45·47	76
77	62·29	45·26	62·10	45·53	61·90	45·80	61·70	46·07	77
78	63·10	45·85	62·90	46·12	62·70	46·40	62·50	46·67	78
79	63·91	46·43	63·71	46·71	63·50	46·99	63·30	47·27	79
80	64·72	47·02	64·52	47·30	64·31	47·59	64·10	47·87	80
81	65·53	47·61	65·32	47·90	65·11	48·18	64·90	48·46	81
82	66·34	48·20	66·13	48·49	65·92	48·78	65·70	49·06	82
83	67·15	48·79	66·93	49·08	66·72	49·37	66·50	49·66	83
84	67·96	49·37	67·74	49·67	67·52	49·97	67·31	50·26	84
85	68·77	49·96	68·55	50·26	68·33	50·56	68·11	50·86	85
86	69·58	50·55	69·35	50·85	69·13	51·15	68·91	51·46	86
87	70·38	51·14	70·16	51·44	69·94	51·75	69·71	52·05	87
88	71·19	51·73	70·97	52·04	70·74	52·34	70·51	52·65	88
89	72·00	52·31	71·77	52·63	71·54	52·94	71·31	53·25	89
90	72·81	52·90	72·58	53·22	72·35	53·53	72·11	53·85	90
91	73·62	53·49	73·39	53·81	73·15	54·13	72·91	54·45	91
92	74·43	54·08	74·19	54·40	73·95	54·72	73·72	55·05	92
93	75·24	54·66	75·00	54·99	74·76	55·32	74·52	55·64	93
94	76·05	55·25	75·81	55·58	75·56	55·91	75·32	56·24	94
95	76·86	55·84	76·61	56·17	76·37	56·51	76·12	56·84	95
96	77·67	56·43	77·42	56·77	77·17	57·10	76·92	57·44	96
97	78·47	57·02	78·23	57·36	77·97	57·70	77·72	58·04	97
98	79·28	57·60	79·03	57·95	78·78	58·29	78·52	58·64	98
99	80·09	58·19	79·84	58·54	79·58	58·89	79·32	59·23	99
100	80·90	58·78	80·64	59·13	80·39	59·48	80·13	59·83	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	54 Deg.		53¾ Deg.		53½ Deg.		53¼ Deg.		

Distance.	36 Deg.		36¼ Deg.		36½ Deg.		36¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·81	0·59	0·81	0·59	0·80	0·59	0·80	0·60	1
2	1·62	1·18	1·61	1·18	1·61	1·19	1·60	1·20	2
3	2·43	1·76	2·42	1·77	2·41	1·78	2·40	1·79	3
4	3·24	2·35	3·23	2·37	3·22	2·38	3·20	2·39	4
5	4·05	2·94	4·03	2·96	4·02	2·97	4·01	2·99	5
6	4·85	3·53	4·84	3·55	4·82	3·57	4·81	3·59	6
7	5·66	4·11	5·65	4·14	5·63	4·16	5·61	4·19	7
8	6·47	4·70	6·45	4·73	6·43	4·76	6·41	4.79	8
9	7·28	5·29	7·26	5·32	7·23	5·35	7·21	5·38	9
10	8·09	5·88	8·06	5·91	8·04	5·95	8·01	5·98	10
11	8·90	6·47	8·87	6·50	8·84	6·54	8·81	6·58	11
12	9·71	7·05	9·68	7·10	9·65	7·14	9·61	7·18	12
13	10·52	7·64	10·48	7·69	10·45	7·73	10·42	7·78	13
14	11·33	8·23	11·29	8·28	11·25	8·33	11·22	8·38	14
15	12·14	8·82	12·10	8·87	12·06	8·92	12·02	8·97	15
16	12·94	9·40	12·90	9·46	12·86	9·52	12·82	9·57	16
17	13·75	9·99	13·71	10·05	13·67	10·11	13·62	10·17	17
18	14·56	10·58	14·52	10·64	14·47	10·71	14·42	10·77	18
19	15·37	11·17	15·32	11·23	15·27	11·30	15·22	11·37	19
20	16·18	11·76	16·13	11·83	16·08	11·90	16·03	11·97	20
21	16·99	12·34	16·94	12·42	16·88	12·49	16·83	12·56	21
22	17·80	12·93	17·74	13·01	17·68	13·09	17·63	13·16	22
23	18·61	13·52	18·55	13·60	18·49	13·68	18·43	13·76	23
24	19·42	14·11	19·35	14·19	19·29	14·28	19·23	14·36	24
25	20·23	14·69	20·16	14·78	20·10	14·87	20·03	14·96	25
26	21·03	15·28	20·97	15·37	20·90	15·47	20·83	15·56	26
27	21·84	15·87	21·77	15·97	21·70	16·06	21·63	16·15	27
28	22·65	16·46	22·58	16·56	22·51	16·65	22·44	16·75	28
29	23·46	17·05	23·39	17·15	23·31	17·25	23·24	17·35	29
30	24·27	17·63	24·19	17·74	24·12	17·84	24·04	17·95	30
31	25·08	18·22	25·00	18·33	24·92	18·44	24·84	18·55	31
32	25·89	18·81	25·81	18·92	25·72	19·03	25·64	19·15	32
33	26·70	19·40	26·61	19·51	26·53	19·63	26·44	19·74	33
34	27·51	19·98	27·42	20·10	27·33	20·22	27·24	20·34	34
35	28·32	20·57	28·23	20·70	28·13	20·82	28·04	20·94	35
36	29·12	21·16	29·03	21·29	28·94	21·41	28·85	21·54	36
37	29·93	21·75	29·84	21·88	29·74	22·01	29·65	22·14	37
38	30·74	22·34	30·64	22·47	30·55	22·60	30·45	22·74	38
39	31·55	22·92	31·45	23·06	31·35	23·20	31·25	23·33	39
40	32·36	23·51	32·26	23·65	32·15	23·79	32·05	23·93	40
41	33·17	24·10	33·06	24·24	32·96	24·39	32·85	24·53	41
42	33·98	24·69	33·87	24·83	33·76	24·98	33·65	25·13	42
43	34·79	25·27	34·68	25·43	34·57	25·58	34·45	25·73	43
44	35·60	25·86	35·48	26·02	35·37	26·17	35·26	26·33	44
45	36·41	26·45	36·29	26·61	36·17	26·77	36·06	26·92	45
46	37·21	27·04	37·10	27·20	36·98	27·36	36·86	27·52	46
47	38·02	27·63	37·90	27·79	37·78	27·96	37·66	28·12	47
48	38·83	28·21	38·71	28·38	38·59	28·55	38·46	28·72	48
49	39·64	28·80	39·52	28·97	39·39	29·15	39·26	29·32	49
50	40·45	29·39	40·32	29·57	40·19	29·74	40·06	29·92	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance
	54 Deg.		53¾ Deg.		53½ Deg.		53¼ Deg.		

Distance.	36 Deg. Lat.	36 Deg. Dep.	36¼ Deg. Lat.	36¼ Deg. Dep.	36½ Deg. Lat.	36½ Deg. Dep.	36¾ Deg. Lat.	36¾ Deg. Dep.	Distance.
51	41·26	29·98	41·13	30·16	41·00	30·34	40·86	30·51	51
52	42·07	30·56	41·94	30·75	41·80	30·93	41·67	31·11	52
53	42·88	31·15	42·74	31·34	42·60	31·53	42·47	31·71	53
54	43·69	31·74	43·55	31·93	43·41	32·12	43·27	32·31	54
55	44·50	32·33	44·35	32·52	44·21	32·72	44·07	32·91	55
56	45·30	32·92	45·16	33·11	45·02	33·31	44·87	33·51	56
57	46·11	33·50	45·97	33·70	45·82	33·90	45·67	34·10	57
58	46·92	34·09	46·77	34·30	46·62	34·50	46·47	34·70	58
59	47·73	34·68	47·58	34·89	47·43	35·09	47·27	35·30	59
60	48·54	35·27	48·39	35·48	48·23	35·69	48·08	35·90	60
61	49·35	35·85	49·19	36·07	49·04	36·28	48·88	36·50	61
62	50·16	36·44	50·00	36·66	49·84	36·88	49·68	37·10	62
63	50·97	37·03	50·81	37·25	50·64	37·47	50·48	37·69	63
64	51·78	37·62	51·61	37·84	51·45	38·07	51·28	38·29	64
65	52·59	38·21	52·42	38·44	52·25	38·66	52·08	38·89	65
66	53·40	38·79	53·23	39·03	53·05	39·26	52·88	39·49	66
67	54·20	39·38	54·03	39·62	53·86	39·85	53·68	40·09	67
68	55·01	39·97	54·84	40·21	54·66	40·45	54·49	40·69	68
69	55·82	40·56	55·64	40·80	55·47	41·04	55·29	41·28	69
70	56·63	41·14	56·45	41·39	56·27	41·64	56·09	41·88	70
71	57·44	41·73	57·26	41·98	57·07	42·23	56·89	42·48	71
72	58·25	42·32	58·06	42·57	57·88	42·83	57·69	43·08	72
73	59·06	42·91	58·87	43·17	58·68	43·42	58·49	43·68	73
74	59·87	43·50	59·68	43·76	59·49	44·02	59·29	44·28	74
75	60·68	44·08	60·48	44·35	60·29	44·61	60·09	44·87	75
76	61·49	44·67	61·29	44·94	61·09	45·21	60·90	45·47	76
77	62·29	45·26	62·10	45·53	61·90	45·80	61·70	46·07	77
78	63·10	45·85	62·90	46·12	62·70	46·40	62·50	46·67	78
79	63·91	46·43	63·71	46·71	63·50	46·99	63·30	47·27	79
80	64·72	47·02	64·52	47·30	64·31	47·59	64·10	47·87	80
81	65·53	47·61	65·32	47·90	65·11	48·18	64·90	48·46	81
82	66·34	48·20	66·13	48·49	65·92	48·78	65·70	49·06	82
83	67·15	48·79	66·93	49·08	66·72	49·37	66·50	49·66	83
84	67·96	49·37	67·74	49·67	67·52	49·97	67·31	50·26	84
85	68·77	49·96	68·55	50·26	68·33	50·56	68·11	50·86	85
86	69·58	50·55	69·35	50·85	69·13	51·15	68·91	51·46	86
87	70·38	51·14	70·16	51·44	69·94	51·75	69·71	52·05	87
88	71·19	51·73	70·97	52·04	70·74	52·34	70·51	52·65	88
89	72·00	52·31	71·77	52·63	71·54	52·94	71·31	53·25	89
90	72·81	52·90	72·58	53·22	72·35	53·53	72·11	53·85	90
91	73·62	53·49	73·39	53·81	73·15	54·13	72·91	54·45	91
92	74·43	54·08	74·19	54·40	73·95	54·72	73·72	55·05	92
93	75·24	54·66	75·00	54·99	74·76	55·32	74·52	55·64	93
94	76·05	55·25	75·81	55·58	75·56	55·91	75·32	56·24	94
95	76·86	55·84	76·61	56·17	76·37	56·51	76·12	56·84	95
96	77·67	56·43	77·42	56·77	77·17	57·10	76·92	57·44	96
97	78·47	57·02	78·23	57·36	77·97	57·70	77·72	58·04	97
98	79·28	57·60	79·03	57·95	78·78	58·29	78·52	58·64	98
99	80·09	58·19	79·84	58·54	79·58	58·89	79·32	59·23	99
100	80·90	58·78	80·64	59·13	80·39	59·48	80·13	59·83	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	54 Deg.		53¾ Deg.		53½ Deg.		53¼ Deg.		

Distance.	37 Deg.		37¼ Deg.		37½ Deg.		37¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·80	0·60	0·80	0·61	0·79	0·61	0·79	0·61	1
2	1·60	1·20	1·59	1·21	1·59	1·22	1·58	1·22	2
3	2·40	1·81	2·39	1·82	2·38	1·83	2·37	1·84	3
4	3·19	2·41	3·18	2·42	3·17	2·43	3·16	2·45	4
5	3·99	3·01	3·98	3·03	3·97	3·04	3·95	3·06	5
6	4·79	3·61	4·78	3·63	4·76	3·65	4·74	3·67	6
7	5·59	4·21	5·57	4·24	5·55	4·26	5·53	4·29	7
8	6·39	4·81	6·37	4·84	6·35	4·87	6·33	4·90	8
9	7·19	5·42	7·16	5·45	7·14	5·48	7·12	5·51	9
10	7·99	6·02	7·96	6·05	7·93	6·09	7·91	6·12	10
11	8·78	6·62	8·76	6·66	8·73	6·70	8·70	6·73	11
12	9·58	7·22	9·55	7·26	9·52	7·31	9·49	7·35	12
13	10·38	7·82	10·35	7·87	10·31	7·91	10·28	7·96	13
14	11·18	8·43	11·14	8·47	11·11	8·52	11·07	8·57	14
15	11·98	9·03	11·94	9·08	11·90	9·13	11·86	9·18	15
16	12·78	9·63	12·74	9·68	12·69	9·74	12·65	9·80	16
17	13·58	10·23	13·53	10·29	13·49	10·35	13·44	10·41	17
18	14·38	10·83	14·33	10·90	14·28	10·96	14·23	11·02	18
19	15·17	11·43	15·12	11·50	15·07	11·57	15·02	11·63	19
20	15·97	12·04	15·92	12·11	15·87	12·18	15·81	12·24	20
21	16·77	12·64	16·72	12·71	16·66	12·78	16·60	12·86	21
22	17·57	13·24	17·51	13·32	17·45	13·39	17·40	13·47	22
23	18·37	13·84	18·31	13·92	18·25	14·00	18·19	14·08	23
24	19·17	14·44	19·10	14·53	19·04	14·61	18·98	14·69	24
25	19·97	15·05	19·90	15·13	19·83	15·22	19·77	15·31	25
26	20·76	15·65	20·70	15·74	20·63	15·83	20·56	15·92	26
27	21·56	16·25	21·49	16·34	21·42	16·44	21·35	16·53	27
28	22·36	16·85	22·29	16·95	22·21	17·05	22·14	17·14	28
29	23·16	17·45	23·08	17·55	23·01	17·65	22·98	17·75	29
30	23·96	18·05	23·88	18·16	23·80	18·26	23·72	18·37	30
31	24·76	18·66	24·68	18·76	24·59	18·87	24·51	18·98	31
32	25·56	19·26	25·47	19·37	25·39	19·48	25·30	19·59	32
33	26·35	19·86	26·27	19·97	26·18	20·09	26·09	20·20	33
34	27·15	20·46	27·06	20·58	26·97	20·70	26·88	20·82	34
35	27·95	21·06	27·86	21·19	27·77	21·31	27·67	21·43	35
36	28·75	21·67	28·66	21·79	28·56	21·92	28·46	22·04	36
37	29·55	22·27	29·45	22·40	29·35	22·52	29·26	22·65	37
38	30·35	22·87	30·25	23·00	30·15	23·13	30·05	23·26	38
39	31·15	23·47	31·04	23·61	30·94	23·74	30·84	23·88	39
40	31·95	24·07	31·84	24·21	31·73	24·35	31·63	24·49	40
41	32·74	24·67	32·64	24·82	32·53	24·96	32·42	25·10	41
42	33·54	25·28	33·43	25·42	33·32	25·57	33·21	25·71	42
43	34·34	25·88	34·23	26·03	34·11	26·18	34·00	26·33	43
44	35·14	26·48	35·02	26·63	34·91	26·79	34·79	26·94	44
45	35·94	27·08	35·82	27·24	35·70	27·39	35·58	27·55	45
46	36·74	27·68	36·62	27·84	36·49	28·00	36·37	28·16	46
47	37·54	28·29	37·41	28·45	37·29	28·61	37·16	28·77	47
48	38·33	28·89	38·21	29·05	38·08	29·22	37·95	29·39	48
49	39·13	29·49	39·00	29·66	38·87	29·83	38·74	30·00	49
50	39·93	30·09	39·80	30·26	39·67	30·44	39·53	30·61	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	53 Deg.		52¾ Deg.		52½ Deg.		52¼ Deg.		

Distance.	37 Deg.		37¼ Deg.		37½ Deg.		37¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	40·73	30·69	40·60	30·87	40·46	31·05	40·33	31·22	51
52	41·53	31·29	41·39	31·48	41·25	31·66	41·12	31·84	52
53	42·33	31·90	42·19	32·08	42·05	32·26	41·91	32·45	53
54	43·13	32·50	42·98	32·69	42·84	32·87	42·70	33·06	54
55	43·92	33·10	43·78	33·29	43·63	33·48	43·49	33·67	55
56	44·72	33·70	44·58	33·90	44·43	34·09	44·28	34·28	56
57	45·52	34·30	45·37	34·50	45·22	34·70	45·07	34·90	57
58	46·32	34·91	46·17	35·11	46·01	35·31	45·86	35·51	58
59	47·12	35·51	46·96	35·71	46·81	35·92	46·65	36·12	59
60	47·92	36·11	47·76	36·32	47·60	36·53	47·44	36·73	60
61	48·72	36·71	48·56	36·92	48·39	37·13	48·23	37·35	61
62	49·52	37·31	49·35	37·53	49·19	37·74	49·02	37·96	62
63	50·31	37·91	50·15	38·13	49·98	38·35	49·81	38·57	63
64	51·11	38·52	50·94	38·74	50·77	38·96	50·60	39·18	64
65	51·91	39·12	51·74	39·34	51·57	39·57	51·39	39·79	65
66	52·71	39·72	52·54	39·95	52·36	40·18	52·19	40·41	66
67	53·51	40·32	53·33	40·55	53·15	40·79	52·98	41·02	67
68	54·31	40·92	54·13	41·16	53·95	41·40	53·77	41·63	68
69	55·11	41·53	54·92	41·77	54·74	42·00	54·56	42·24	69
70	55·90	42·13	55·72	42·37	55·53	42·61	55·35	42·86	70
71	56·70	42·73	56·52	42·98	56·33	43·22	56·14	43·47	71
72	57·50	43·33	57·31	43·58	57·12	43·83	56·93	44·08	72
73	58·30	43·93	58·11	44·19	57·91	44·44	57·72	44·69	73
74	59·10	44·53	58·90	44·79	58·71	45·05	58·51	45·30	74
75	59·90	45·14	59·70	45·40	59·50	45·66	59·30	45·92	75
76	60·70	45·74	60·50	46·00	60·29	46·27	60·09	46·53	76
77	61·49	46·34	61·29	46·61	61·09	46·87	60·88	47·14	77
78	62·29	46·94	62·09	47·21	61·88	47·48	61·67	47·75	78
79	63·09	47·54	62·88	47·82	62·67	48·09	62·46	48·37	79
80	63·89	48·15	63·68	48·42	63·47	48·70	63·26	48·98	80
81	64·69	48·75	64·48	49·03	64·26	49·31	64·05	49·59	81
82	65·49	49·35	65·27	49·63	65·05	49·92	64·84	50·20	82
83	66·29	49·95	66·07	50·24	65·85	50·53	65·63	50·81	83
84	67·09	50·55	66·86	50·84	66·64	51·14	66·42	51·43	84
85	67·88	51·15	67·66	51·45	67·43	51·74	67·21	52·04	85
86	68·68	51·76	68·46	52·06	68·23	52·35	68·00	52·65	86
87	69·48	52·36	69·25	52·66	69·02	52·96	68·79	53·26	87
88	70·28	52·96	70·05	53·27	69·82	53·57	69·58	53·88	88
89	71·08	53·56	70·84	53·87	70·61	54·18	70·37	54·49	89
90	71·88	54·16	71·64	54·48	71·40	54·79	71 16	55·10	90
91	72·68	54·77	72·44	55·08	72·20	55·40	71·95	55·71	91
92	73·47	55·37	73·23	55·69	72 99	56·01	72·74	56·32	92
93	74·27	55·97	74·03	56·29	73·78	56·61	73·53	56·94	93
94	75·07	56·57	74·82	56·90	74·58	57·22	74·32	57·55	94
95	75·87	57·17	75·62	57·50	75·37	57·83	75·12	58·16	95
96	76·67	57·77	76·42	58·11	76·16	58·44	75·91	58·77	96
97	77·47	58·38	77·21	58·71	76·96	59·05	76·70	59·30	97
98	78·27	58·98	78·01	59·32	77·75	59·66	77·49	60·00	98
99	79·06	59·58	78·80	59·92	78·54	60·27	78·28	60·61	99
100	79·86	60·18	79·60	60·53	79·34	60·88	79·07	61·22	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep .	Lat.	Dep.	Lat.	Distance.
	53 Deg.		52¾ Deg.		52½ Deg.		52¼ Deg.		

Distance.	38 Deg. Lat.	38 Deg. Dep.	38¼ Deg. Lat.	38¼ Deg. Dep.	38½ Deg. Lat.	38½ Deg. Dep.	38¾ Deg. Lat.	38¾ Deg. Dep.	Distance.
1	0·79	0·62	0·79	0·62	0·78	0·62	0·78	0·63	1
2	1·58	1·23	1·57	1·24	1·57	1·24	1·56	1·25	2
3	2·36	1·85	2·36	1·86	2·35	1·87	2·34	1·88	3
4	3·15	2·46	3·14	2·48	3·13	2·49	3·12	2·50	4
5	3·94	3·08	3·93	3·10	3·91	3·11	3·90	3·13	5
6	4·73	3·69	4·71	3·71	4·70	3·74	4·68	3·76	6
7	5·52	4·31	5·50	4·33	5·48	4·36	5·46	4·38	7
8	6·30	4·93	6·28	4·95	6·26	4·98	6·24	5·01	8
9	7·09	5·54	7·07	5·57	7·04	5·60	7·02	5·63	9
10	7·88	6·16	7·85	6·19	7·83	6·23	7·80	6·26	10
11	8·67	6·77	8·64	6·81	8·61	6·85	8·58	6·89	11
12	9·46	7·39	9·42	7·43	9·39	7·47	9·36	7·51	12
13	10·24	8·00	10·21	8·05	10·17	8·09	10·14	8·14	13
14	11·03	8·62	10·99	8·67	10·96	8·72	10·92	8·76	14
15	11·82	9·23	11·78	9·29	11·74	9·34	11·70	9·39	15
16	12·61	9·85	12·57	9·91	12·52	9·96	12·48	10·01	16
17	13·40	10·47	13·35	10·52	13·30	10·58	13·26	10·64	17
18	14·18	11·08	14·14	11·14	14·09	11·21	14·04	11·27	18
19	14·97	11·70	14·92	11·76	14·87	11·83	14·82	11·89	19
20	15·76	12·31	15·71	12·38	15·65	12·45	15·60	12·52	20
21	16·55	12·93	16·49	13·00	16·43	13·07	16·38	13·14	21
22	17·34	13·54	17·28	13·62	17·22	13·70	17·16	13·77	22
23	18·12	14·16	18·06	14·24	18·00	14·32	17·94	14·40	23
24	18·91	14·78	18·85	14·86	18·78	14·94	18·72	15·02	24
25	19·70	15·39	19·63	15·48	19·57	15·56	19·50	15·65	25
26	20·49	16·01	20·42	16·10	20 35	16·19	20·28	16·27	26
27	21·28	16·62	21·20	16·72	21·13	16·81	21·06	16·90	27
28	22·06	17·24	21·99	17·33	21·91	17·43	21·84	17·53	28
29	22·85	17·85	22·77	17·95	22·70	18·05	22·62	18·15	29
30	23·64	18·47	23·56	18·57	23·48	18·68	23·40	18·78	30
31	24·43	19·09	24·34	19·19	24·26	19·30	24·18	19·40	31
32	25·22	19·70	25·13	19·81	25·04	19·92	24·96	20·03	32
33	26·00	20·32	25·92	20·43	25·83	20·54	25·74	20·66	33
34	26·79	20·93	26·70	21·05	26·61	21·17	26·52	21·28	34
35	27·58	21·55	27·49	21·67	27·39	21·79	27·30	21·91	35
36	28·37	22·16	28·27	22·29	28·17	22·41	28·08	22·53	36
37	29·16	22·78	29·06	22·91	28·96	23·03	28·86	23·16	37
38	29·94	23·40	29·84	23·53	29·74	23·66	29·64	23·79	38
39	30·73	24·01	30·63	24·14	30·52	24·28	30·42	24·41	39
40	31·52	24·63	31·41	24·76	31·30	24·90	31·20	25·04	40
41	32·31	25·24	32·20	25·38	32·09	25·52	31·98	25·66	41
42	33·10	25·86	32·98	26·00	32·87	26·15	32·76	26·29	42
43	33·88	26·47	33·77	26·62	33·65	26·77	33·53	26·91	43
44	34·67	27·09	34·55	27·24	34·43	27·39	34·31	27·54	44
45	35·46	27·70	35·34	27·86	35·22	28·01	35·09	28·17	45
46	36·25	28·32	36·12	28·48	36·00	28·64	35·87	28·79	46
47	37·04	28·94	36·91	29·10	36·78	29·26	36·65	29·42	47
48	37·82	29·55	37·70	29·72	37·57	29·88	37·43	30·04	48
49	38·61	30·17	38·48	30·34	38·35	30·50	38·21	30·67	49
50	39·40	30·78	39·27	30·95	39·13	31·13	38·99	31·30	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	52 Deg.		51¾ Deg.		51½ Deg.		51¼ Deg.		

Distance.	38 Deg.		38¼ Deg.		38½ Deg.		38¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	40·19	31·40	40·05	31·57	39·91	31·75	39·77	31·92	51
52	40·98	32·01	40·84	32·19	40·70	32·37	40·55	32·55	52
53	41·76	32·63	41·62	32·81	41·48	32·99	41·33	33·17	53
54	42·55	33·25	42·41	33·43	42·26	33·62	42·11	33·80	54
55	43·34	33·86	43·19	34·05	43·04	34·24	42·89	34·43	55
56	44·13	34·48	43·98	34·67	43·83	34·86	43·67	35·05	56
57	44·92	35·09	44·76	35·29	44·61	35·48	44·45	35·68	57
58	45·70	35·71	45·55	35·91	45·39	36·11	45·23	36·30	58
59	46·49	36·32	46·33	36·53	46·17	36·73	46·01	46·93	59
60	47·28	36·94	47·12	37·15	46 96	37·35	46·79	37·56	60
61	48·07	37·56	47·90	37·76	47·74	37·97	47·57	38·18	61
62	48·86	38·17	48 69	38·38	48·52	38·60	48·35	38·81	62
63	49·64	38·79	49·47	39·00	49·30	39·22	49·13	39·43	63
64	50·43	39·40	50·26	39·62	50·09	39·84	49·91	40·06	64
65	51·22	40·02	51·05	40·24	50·87	40·46	50·69	40·68	65
66	52·01	40·63	51·83	40·86	51·65	41·09	51·47	41·31	66
67	52·80	41·25	52·62	41·48	52·43	41·71	52·25	41·94	67
68	53·58	41·86	53·40	42·10	53·22	42·33	53·03	42·56	68
69	54·37	42·48	54·19	42·72	54·00	42·95	53·81	43·19	69
70	55·16	43·10	54·97	43·34	54·78	43·58	54·59	43·81	70
71	55·95	43·71	55·76	43·96	55·57	44·20	55·37	44·44	71
72	56·74	44·33	56·54	44·57	56·35	44·82	56·15	45·07	72
73	57·52	44·94	57·33	45·19	57·13	45·44	56·93	45·69	73
74	58·31	45·56	58·11	45·81	57·91	46·07	57·71	46·32	74
75	59·10	46·17	58·90	46·43	58·70	46·69	58·49	46·94	75
76	59·89	46·79	59·68	47·05	59·48	47·31	59·27	47·57	76
77	60·68	47·41	60·47	47·67	60·26	47·93	60·05	48·20	77
78	61·46	48·02	61·25	48·29	61·04	48·56	60·83	48·82	78
79	62·25	48·64	62·04	48·91	61·83	49·18	61·61	49·45	79
80	63·04	49·25	62·83	49·53	62·61	49·80	62·39	50·07	80
81	63·83	49 87	63·61	50·15	63·39	50·42	63·17	50·70	81
82	64·62	50·48	64·40	50·77	64·17	51·05	63·95	51·33	82
83	65·40	51·10	65·18	51·38	64·96	51·67	64·73	51·95	83
84	66·19	51·72	65·97	52·00	65·74	52·29	65·51	52·58	84
85	66·98	52·33	66·75	52·62	66·52	52·91	66·29	53·20	85
86	67·77	52·95	67·54	53·24	67·30	53·54	67·07	53·83	86
87	68·56	53·56	68·32	53·86	68·09	54·16	67·85	54·46	87
88	69·34	54·18	69·11	54·48	68·87	54·78	68·63	55·08	88
89	70·13	54·79	69 89	55·10	69·65	55·40	69·41	55·71	89
90	70·92	55·41	70·68	55·72	70·43	56·03	70·19	56·33	90
91	71·71	56·03	71·46	56·34	71·22	56·65	70·97	56·96	91
92	72·50	56·64	72·25	56·96	72·00	57·27	71·75	57·58	92
93	73·28	57·26	73·03	57·58	72·78	57·89	72·53	58·21	93
94	74·07	57·87	73·82	58·19	73·57	58·52	73·31	58·84	94
95	74·86	58·49	74·61	58·81	74·35	59·14	74·09	59·46	95
96	75·65	59·10	75·39	59·43	75·13	59·76	74·87	60·09	96
97	76·44	59·72	76·18	60·05	75·91	60·38	75·65	60·71	97
98	77·22	60·33	76·96	60·67	76·70	61·01	76·43	61·34	98
99	78·01	60·95	77·75	61·29	77·48	61·63	77·21	61·97	99
100	78·80	61·57	78·53	61·91	78·26	62·25	77·99	62·59	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	52 Deg.		51¾ Deg.		51½ Deg.		51¼ Deg.		

Distance.	39 Deg.		39¼ Deg.		39½ Deg.		39¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·78	0·63	0·77	0·63	0·77	0·64	0·77	0·64	1
2	1·55	1·26	1·55	1·27	1·54	1·27	1·54	1·28	2
3	2·33	1·89	2·32	1·90	2·31	1·91	2·31	1·92	3
4	3·11	2·52	3·10	2·53	3·09	2·54	3·08	2·56	4
5	3·89	3·15	3·87	3·16	3·86	3·18	3·84	3·20	5
6	4·66	3·78	4·65	3·80	4·63	3·82	4·61	3·84	6
7	5·44	4·41	5·42	4·43	5·40	4·45	5·38	4·48	7
8	6·22	5·03	6·20	5·06	6·17	5·09	6·15	5·12	8
9	6·99	5·66	6·97	5·69	6·94	5·72	6·92	5·75	9
10	7·77	6·29	7·74	6·33	7·72	6·36	7·69	6·39	10
11	8·55	6·92	8·52	6·96	8·49	7·00	8·46	7.03	11
12	9·33	7·55	9·29	7·59	9·26	7·63	9·23	7·67	12
13	10·10	8·18	10·07	8·23	10·03	8·27	9·99	8·31	13
14	10·88	8·81	10·84	8·86	10·80	8·91	10·76	8·95	14
15	11·66	9·44	11·62	9·49	11·57	9·54	11·53	9·59	15
16	12·43	10·07	12·39	10·12	12·35	10·18	12·30	10·23	16
17	13·21	10·70	13·16	10·76	13·12	10·81	13·07	10·87	17
18	13·99	11·33	13·94	11·39	13·89	11·45	13·84	11·51	18
19	14·77	11·96	14·71	12·02	14·66	12·09	14·61	12·15	19
20	15·54	12·59	15·49	12·65	15·43	12·72	15·38	12·79	20
21	16·32	13·22	16·26	13·29	16·20	13·36	16·15	13·43	21
22	17·10	13·84	17·04	13·92	16·98	13·99	16·91	14·07	22
23	17·87	14·47	17·81	14·55	17·75	14·63	17·68	14·71	23
24	18·65	15·10	18·59	15·18	18·52	15·27	18·45	15·35	24
25	19·43	15·73	19·36	15·82	19·29	15·90	19·22	15·99	25
26	20·21	16·36	20·13	16·45	20·06	16·54	19·99	16·63	26
27	20·98	16·99	20·91	17·08	20·83	17·17	20·76	17·26	27
28	21·76	17·62	21·68	17·72	21·61	17·81	21·53	17·90	28
29	22·54	18·25	22·46	18·35	22·38	18·45	22·30	18·54	29
30	23·31	18·88	23·23	18·98	23·15	19·08	23·07	19·18	30
31	24·09	19·51	24·01	19·61	23·92	19·72	23·83	19·82	31
32	24·87	20·14	24·78	20·25	24·69	20·35	24·60	20·46	32
33	25·65	20·77	25·55	20·88	25·46	20·99	25·37	21·10	33
34	26·42	21·40	26·33	21·51	26·24	21·63	26·14	21·74	34
35	27·20	22·03	27·10	22·14	27·01	22·26	26·91	22·38	35
36	27·98	22·66	27·88	22·78	27·78	22·90	27·68	23·02	36
37	28·75	23·28	28·65	23·41	28·55	23·53	28·45	23·66	37
38	29·53	23·91	29·43	24·04	29·32	24·17	29·22	24·30	38
39	30·31	24·54	30·20	24·68	30·09	24·81	29·98	24·94	39
40	31·09	25·17	30·98	25·31	30·86	25·44	30·75	25·58	40
41	31·86	25·80	31·75	25·94	31·64	26·08	31·52	26·22	41
42	32·64	26·43	32·52	26·57	32·41	26·72	32·29	26·86	42
43	33·42	27·06	33·30	27·21	33·18	27·35	33·06	27·50	43
44	34·19	27·69	34·07	27·84	33·95	27·99	33·83	28·14	44
45	34·97	28·32	34·85	28·47	34·72	28·62	34·60	28·77	45
46	35·75	28·95	35·62	29·10	35·49	29·26	35·37	29·41	46
47	36·53	29·58	36·40	29·74	36·27	29·90	36·14	30·05	47
48	37·30	30·21	37·17	30·37	37·04	30·54	36·90	30·69	48
49	38·08	30·84	37·95	31·00	37·81	31·17	37·67	31·33	49
50	38·86	31·47	38·72	31·64	38·58	31·80	38·44	31·97	50
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
Distance.	51 Deg.		50¾ Deg.		50½ Deg.		50¼ Deg.		Distance.

Distance.	39 Deg. Lat.	39 Deg. Dep.	39¼ Deg. Lat.	39¼ Deg. Dep.	39½ Deg. Lat.	39½ Deg. Dep.	39¾ Deg. Lat.	39¾ Deg. Dep.	Distance.
51	39·63	32·10	39·49	32·27	39·35	32·44	39·21	32·61	51
52	40·41	32·72	40·27	32·90	40·12	33·08	39·98	33·25	52
53	41·19	33·35	41·04	33·53	40·90	33·71	40·75	33·89	53
54	41·97	33·98	41·82	34·17	41·67	34·35	41·52	34·53	54
55	42·74	34·61	42·59	34·80	42·44	34·98	42·29	35·17	55
56	43·52	35·24	43·37	35·43	43·21	35·62	43·06	35·81	56
57	44·30	35·87	44·14	36·06	43·98	36·26	43·82	36·45	57
58	45·07	36·50	44·91	36·70	44·75	36·89	44·59	37·09	58
59	45·85	37·13	45·69	37·33	45·53	37·53	45·36	37·73	59
60	46·63	37·76	46·46	37·96	46·30	38·16	46·13	38·37	60
61	47·41	38·39	47·24	38·60	47·07	38·80	46·90	39·01	61
62	48·18	39·02	48·01	39·23	47·84	39·44	47·67	39·65	62
63	48·96	39·65	48·79	39·86	48·61	40·07	48·44	40·28	63
64	49·74	40·28	49·56	40·49	49·38	40·71	49·21	40·92	64
65	50·51	40·91	50·34	41·13	50·16	41·35	49·97	41·56	65
66	51·29	41·54	51·11	41·76	50·93	41·98	50·74	42·20	66
67	52·07	42·16	51·88	42·39	51·70	42·62	51·51	42·84	67
68	52·85	42·79	52·66	43·02	52·47	43·25	52·28	43·48	68
69	53·52	43·42	53·43	43·66	53·24	43·89	53·05	44·12	69
70	54·40	44·05	54·21	44·29	54·01	44·53	53·82	44·76	70
71	55·18	44·68	54·98	44·92	54·79	45·16	54·59	45·40	71
72	55·95	45·31	55·76	45·55	55·56	45·80	55·36	46·04	72
73	56·73	45·94	56·53	46·19	56·33	46·43	56·13	46·68	73
74	57·51	46·57	57·31	46·82	57·10	47·07	56·89	47·32	74
75	58·29	47·20	58·08	47·45	57·87	47·71	57·66	47·96	75
76	59·06	47·83	58·85	48·09	58·64	48·34	58·43	48·60	76
77	59·84	48·46	59·63	48·72	59·42	48·98	59·20	49·24	77
78	60·62	49·09	60·40	49·35	60·19	49·61	59·97	49·88	78
79	61·39	49·72	61·18	49·98	60·96	50·25	60·74	50·52	79
80	62·17	50·35	61·95	50·62	61·73	50·89	61·51	51·16	80
81	62·95	50·97	62·73	51·25	62·50	51·52	62·28	51·79	81
82	63·73	51·60	63·50	51·88	63·27	52·16	63·04	52·43	82
83	64·50	52·23	64·27	52·51	64·04	52·79	63·81	53·07	83
84	65·28	52·86	65·05	53·15	64·82	53·43	64·58	53·71	84
85	66·06	53·49	65·82	53·78	65·59	54·07	65·35	54·35	85
86	66·83	54·12	66·60	54·41	66·36	54·70	66·12	54·99	86
87	67·61	54·75	67·37	55·05	67·13	55·34	66·89	55·63	87
88	68·39	55·38	68·15	55·68	67·90	55·97	67·66	56·27	88
89	69·17	56·01	68·92	56·32	68·67	56·61	68·43	56·91	89
90	69·94	56·64	69·70	56·94	69·45	57·25	69·20	57·55	90
91	70·72	57·27	70·47	57·58	70·22	57·88	69·96	58·19	91
92	71·50	57·90	71·24	58·21	70·99	58·52	70·73	58·83	92
93	72·27	58·53	72·02	58·84	71·76	59·16	71·50	59·47	93
94	73·05	59·16	72·79	59·47	72·53	59·79	72·27	60·11	94
95	73·83	59·77	73·57	60·11	73·30	60·43	73·04	60·75	95
96	74·61	60·41	74·34	60·74	74·08	61·06	73·81	61·39	96
97	75·38	61·04	75·12	61·37	74·85	61·70	74·58	62·03	97
98	76·16	61·57	75·89	62·01	75·62	62·34	75·35	62·66	98
99	76·94	62·30	76·66	62·64	76·39	62·97	76·12	63·30	99
100	77·71	62·93	77·44	63·27	77·16	63·61	76·88	63·94	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	51 Deg.		50¾ Deg.		50½ Deg.		50¼ Deg.		

Distance.	40 Deg.		40¼ Deg.		40½ Deg.		40¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·77	0·64	0·76	0·65	0·76	0·65	0·76	0·65	1
2	1·53	1·29	1·53	1·29	1·52	1·30	1·52	1·31	2
3	2·30	1·93	2·29	1·94	2·28	1·95	2·27	1·96	3
4	3·06	2·57	3·05	2·58	3·04	2·60	3·03	2·61	4
5	3·83	3·21	3·82	3·23	3·80	3·25	3·79	3·26	5
6	4·60	3·86	4·58	3·88	4·56	3·90	4·55	3·92	6
7	5·36	4·50	5·34	4·52	5·32	4·55	5·30	4·57	7
8	6·13	5·14	6·11	5·17	6·08	5·20	6·06	5·22	8
9	6·89	5·79	6·87	5·82	6·84	5·84	6·82	5·87	9
10	7·66	6·43	7·63	6·46	7·60	6·49	7·58	6·53	10
11	8·43	7·07	8·40	7·11	8·36	7·14	8·33	7·18	11
12	9·19	7·71	9·16	7·75	9·12	7·79	9·09	7·83	12
13	9·96	8·36	9·92	8·40	9·89	8·44	9·85	8·49	13
14	10·72	9·00	10·69	9·05	10·65	9·09	10·61	9·14	14
15	11·49	9·64	11·45	9·69	11·41	9·74	11·36	9·79	15
16	12·26	10·28	12·21	10·34	12·17	10·39	12·12	10·44	16
17	13·02	10·93	12·97	10·98	12·93	11·04	12·88	11·10	17
18	13·79	11·57	13·74	11·63	13·69	11·69	13·64	11·75	18
19	14·55	12·21	14·50	12·28	14·45	12·34	14·39	12·40	19
20	15·32	12·86	15·26	12·92	15·21	12·99	15·15	13·06	20
21	16·09	13·50	16·03	13·57	15·97	13·64	15·91	13·71	21
22	16·85	14·14	16·79	14·21	16·73	14·29	16·67	14·36	22
23	17·62	14·78	17·55	14·86	17·49	14·94	17·42	15·01	23
24	18·39	15·43	18·32	15·51	18·25	15·59	18·18	15·67	24
25	19·15	16·07	19·08	16·15	19·01	16·24	18·94	16·32	25
26	19·92	16·71	19·84	16·80	19·77	16·89	19·70	16·97	26
27	20·68	17·36	20·61	17·45	20·53	17·54	20·45	17·62	27
28	21·45	18·00	21·37	18·09	21·29	18·18	21·21	18·28	28
29	22·22	18·64	22·13	18·74	22·05	18·83	21·97	18·93	29
30	22·98	19·28	22·90	19·38	22·81	19·48	22·73	19·58	30
31	23·75	19·93	23·66	20·03	23·57	20·13	23·48	20·24	31
32	24·51	20·57	24·42	20·68	24·33	20·78	24·24	20·89	32
33	25·28	21·21	25·19	21·32	25·09	21·43	25·00	21·54	33
34	26·05	21·85	25·95	21·97	25·85	22·08	25·76	22·19	34
35	26·81	22·50	26·71	22·61	26·61	22·73	26·51	22·85	35
36	27·58	23·14	27·48	23·26	27·37	23·38	27·27	23·50	36
37	28·34	23·78	28·24	23·91	28·13	24·03	28·03	24·15	37
38	29·11	24·43	29·00	24·55	28·90	24·68	28·79	24·80	38
39	29·88	25·07	29·77	25·20	29·66	25·33	29·54	25·46	39
40	30·64	25·71	30·53	25·84	30·42	25·98	30·30	26·11	40
41	31·41	26·35	31·29	26·49	31·18	26·63	31·06	26·76	41
42	32·17	27·00	32·06	27·14	31·94	27·28	31·82	27·42	42
43	32·94	27·64	32·82	27·78	32·70	27·93	32·58	28·07	43
44	33·71	28·28	33·58	28·43	33·46	28·58	33·33	28·72	44
45	34·47	28·93	34·35	29·08	34·22	29·23	34·09	29·37	45
46	35·24	29·57	35·11	29·72	34·98	29·87	34·85	30·03	46
47	36·00	30·21	35·87	30·37	35·74	30·52	35·61	30·68	47
48	36·77	30·85	36·64	31·01	36·50	31·17	36·36	31·33	48
49	37·54	31·50	37·40	31·66	37·26	31·82	37·12	31·99	49
50	38·30	32·14	38·16	32·31	38·02	32·47	37·88	32·64	50
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
Distance.	50 Deg.		49¾ Deg.		49½ Deg.		49¼ Deg.		Distance.

Distance.	40 Deg.		40¼ Deg.		40½ Deg.		40¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	39·07	32·78	38·92	32·95	38·78	33·12	38·64	33·29	51
52	39·83	33·42	39·69	33·60	39·54	33·77	39·39	33·94	52
53	40·60	34·07	40·45	34·24	40·30	34·42	40·15	34·60	53
54	41·37	34·71	41·21	34·89	41·06	35·07	40·91	35·25	54
55	42·13	35.35	41·98	35·54	41·82	35·72	41·67	35·90	55
56	42·90	36·00	42·74	36·18	42·58	36·37	42·42	36·55	56
57	43·66	36·64	43·50	36·83	43·34	37·02	43·18	37·21	57
58	44·43	37·28	44·27	37·48	44·10	37·67	43·94	37·86	58
59	45·20	37·92	45·03	38·12	44·86	38·32	44·70	38·51	59
60	45·96	38·57	45·79	38·77	45·62	38·97	45·45	39·17	60

Distance.	40 Deg. Lat.	Dep.	40¼ Deg. Lat.	Dep.	40½ Deg. Lat.	Dep.	40¾ Deg. Lat.	Dep.	Distance.
61	46·73	39·21	46·56	39·41	46·38	39·62	46·21	39·82	61
62	47·49	39·85	47·32	40·06	47·15	40·27	46·97	40·47	62
63	48·26	40·50	48·08	40·71	47·91	40·92	47·73	41·12	63
64	49·03	41·14	48·85	41·35	48·67	41·56	48·48	41·78	64
65	49·79	41·78	49·61	42·00	49·43	42·21	49·24	42·43	65
66	50·56	42·42	50·37	42·64	50·19	42·86	50 00	43·08	66
67	51·32	43·07	51·14	43·29	50·95	43·51	50·76	43·73	67
68	52·09	43·71	51·90	43·94	51·71	44·16	51·51	44·39	68
69	52·86	44·35	52·66	44·58	52·47	44·81	52·27	45·04	69
70	53·62	45·00	53·43	45·23	53·23	45·46	53·03	45·69	70
71	54·39	45·64	54·19	45·87	53·99	46·11	53·79	46·35	71
72	55·16	46·28	54·95	46·52	54·75	46·76	54·54	47·00	72
73	55·92	46·92	55·72	47·17	55·51	47·41	55·30	47·65	73
74	56·69	47·57	56·48	47·81	56·27	48·06	56·06	48·30	74
75	57·45	48·21	57·24	48·46	57·03	48·71	56·82	48·96	75
76	58·22	48·85	58·01	49·11	57·79	49·36	57·57	49·61	76
77	58·99	49·49	58·77	49·75	58·55	50·01	58·33	50·26	77
78	59·75	50·14	59·53	50·40	59·31	50·66	59·09	50·92	78
79	60·52	50·78	60·30	51·04	60·07	51·31	59·85	51·57	79
80	61·28	51·42	61·06	51·69	60·83	51·96	60·61	52·22	80

Distance.	40 Deg. Lat.	Dep.	40¼ Deg. Lat.	Dep.	40½ Deg. Lat.	Dep.	40¾ Deg. Lat.	Dep.	Distance.
81	62·05	52·07	61·82	52·34	61·59	52·61	61·36	52·87	81
82	62·82	52·71	62·59	52·98	62·35	53·25	62·12	53·53	82
83	63·58	53·35	63·35	53·63	63·11	53·90	62·88	54·18	83
84	64·35	53·99	64·11	54·27	63·87	54·55	63·64	54·83	84
85	65·11	54·64	64·87	54 92	64·63	55·20	64·39	55·48	85
86	65 88	55·28	65·64	55·57	65·39	55·85	65·15	56·14	86
87	66·65	55·92	66·40	56·21	66·16	56·50	65·91	56·79	87
88	67·41	56·57	67·16	56·86	66·92	57·15	66·67	57·44	88
89	68·18	57·21	67·93	57·50	67·68	57·80	67·42	58·10	89
90	68·94	57·85	68·69	58·15	68·44	58·45	68·18	58·75	90
91	69·71	58·49	69·45	58·80	69·20	59·10	68·94	59·40	91
92	70·48	59·14	70·22	59·44	69·96	59·75	69·70	60·05	92
93	71·24	59·78	70·98	60·09	70·72	60·40	70·45	60·71	93
94	72·01	60·42	71·74	60·74	71·48	61·05	71·21	61·36	94
95	72·77	61·06	72·51	61·38	72·24	61·70	71·97	62·01	95
96	73·54	61·71	73·27	62·03	73·00	62·35	72·73	62·66	96
97	74·31	62·35	74·03	62·67	73·76	63·00	73·48	63·32	97
98	75·07	62·99	74·80	63·32	74·52	63·65	74·24	63·97	98
99	75·84	63·64	75·56	63·97	75·28	64·30	75·00	64·62	99
100	76·60	64·28	76·32	64·61	76·04	64·94	75·76	65·28	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	50 Deg.		49¾ Deg.		49½ Deg.		49¼ Deg.		

Distance.	41 Deg. Lat.	41 Deg. Dep.	41¼ Deg. Lat.	41¼ Deg. Dep.	41½ Deg. Lat.	41½ Deg. Dep.	41¾ Deg. Lat.	41¾ Deg. Dep.	Distance.
1	0·75	0·66	0·75	0·66	0·75	0·66	0·75	0·67	1
2	1·51	1·31	1.50	1·32	1·50	1·33	1·49	1·33	2
3	2·26	1·97	2·26	1·98	2·25	1·99	2·24	2·00	3
4	3·02	2·62	3·01	2·64	3·00	2·65	2·98	2·66	4
5	3·77	3·28	3·76	3·30	3·74	3·31	3·73	3·33	5
6	4·53	3·94	4·51	3·96	4·49	3·98	4·48	4·00	6
7	5·28	4·59	5·26	4·62	5·24	4·64	5·22	4·66	7
8	6·04	5·25	6·01	5·27	5·99	5·30	5·97	5·33	8
9	6·79	5·90	6·77	5·93	6·74	5·96	6·71	5·99	9
10	7·55	6·56	7·52	6·59	7·49	6·63	7·46	6·66	10
11	8·30	7·22	8·27	7·25	8·24	7·29	8·21	7·32	11
12	9·06	7·87	9·02	7·91	8·99	7·95	8·95	7·99	12
13	9·81	8·53	9·77	8·57	9·74	8·61	9·70	8·66	13
14	10·57	9·18	10·53	9·23	10·49	9·28	10·44	9·32	14
15	11·32	9·84	11·28	9·89	11·23	9·94	11·19	9·99	15
16	12·08	10·50	12·03	10·55	11·98	10·60	11·94	10·65	16
17	12·83	11·15	12·78	11·21	12·73	11·26	12·68	11·32	17
18	13·58	11·81	13·53	11·87	13·48	11·93	13·43	11·99	18
19	14·34	12·47	14·28	12·53	14·23	12·59	14·18	12·65	19
20	15·09	13·12	15·04	13·19	14·98	13·25	14·92	13·32	20
21	15·85	13·78	15·79	13·85	15·73	13·91	15·67	13·98	21
22	16·60	14·43	16·54	14·51	16·48	14·58	16·41	14·65	22
23	17·36	15·09	17·29	15·16	17·23	15·24	17·16	15·32	23
24	18·11	15·75	18·04	15·82	17·97	15·90	17·91	15·98	24
25	18·87	16·40	18·80	16·48	18·72	16·57	18·65	16·65	25
26	19·62	17·06	19·55	17·14	19·47	17·23	19·40	17·31	26
27	20·38	17·71	20·30	17·80	20·22	17·89	20·14	17·98	27
28	21·13	18·37	21·05	18·46	20·97	18·55	20·89	18·64	28
29	21·89	19·03	21·80	19·12	21·72	19·22	21·64	19·31	29
30	22·64	19·68	22·56	19·78	22·47	19·88	22·38	19·98	30
31	23·40	20·34	23·31	20·44	23·22	20·54	23·13	20·64	31
32	24·15	20·99	24·06	21·10	23·97	21·20	23·87	21·31	32
33	24·91	21·65	24·81	21·76	24·72	21·87	24·62	21·97	33
34	25·66	22·31	25·56	22·42	25·46	22·53	25·37	22·64	34
35	26·41	22·96	26·31	23·08	26·21	23·19	26·11	23·31	35
36	27·17	23·62	27·07	23·74	26·96	23·85	26·86	23·97	36
37	27·92	24·27	27·82	24·40	27·71	24·52	27·60	24·64	37
38	28·68	24·93	28·57	25·06	28·46	25·18	28·35	25·30	38
39	29·43	25·59	29·32	25·71	29·21	25·84	29·10	25·97	39
40	30·19	26·24	30·07	26·37	29·96	26·50	29·84	26·64	40
41	30·94	26·90	30·83	27·03	30·71	27·17	30·59	27·30	41
42	31·70	27·55	31·58	27·69	31·46	27·83	31·33	27·97	42
43	32·45	28·21	32·33	28·35	32·21	28·49	32·08	28·63	43
44	33·21	28·87	33·08	29·01	32·95	29·16	32·83	29·30	44
45	33·96	29·52	33·83	29·67	33·70	29·82	33·57	29·97	45
46	34·72	30·18	34·58	30·33	34·45	30·48	34·32	30·63	46
47	35·47	30·83	35·34	30·99	35·20	31·14	35·06	31·30	47
48	36·23	31·49	36·09	31·65	35.95	31·81	35·81	31·96	48
49	36·98	32·15	36·84	32·31	36·70	32·47	36·56	32·63	49
50	37·74	32·80	37·59	32·97	37·45	33·13	37·30	33·29	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	49 Deg.		48¾ Deg.		48½ Deg.		48¼ Deg.		

Distance.	41 Deg.		41¼ Deg.		41½ Deg.		41¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	38·49	33·46	38·34	33·63	38·20	33·79	38·05	33·96	51
52	39·24	34·12	39·10	34·29	38·95	34·46	38·79	34·63	52
53	40·00	34·77	39·85	34·95	39·69	35·12	39·54	35·29	53
54	40·75	35·43	40·60	35·60	40·44	35·78	40·29	35·96	54
55	41·51	36·08	41·35	36·26	41·19	36·44	41·03	36·62	55
56	42·26	36·74	42·10	36·92	41·94	37·11	41·78	37·29	56
57	43·02	37·40	42·85	37·58	42·69	37·77	42·53	37·96	57
58	43·77	38·05	43·61	38·24	43·44	38·43	43·27	38·62	58
59	44·53	38·71	44·36	38·90	44·19	39·09	44·02	39·29	59
60	45·28	39·36	45·11	39·56	44·94	39·76	44·76	39·95	60
61	46·04	40·02	45·86	40·22	45·69	40·42	45·51	40·62	61
62	46·79	40·68	46·61	40·88	46·44	41·08	46·26	41·28	62
63	47·55	41·33	47·37	41·54	47·18	41·75	47·00	41·95	63
64	48·30	41·99	48·12	42·20	47·93	42·41	47·75	42·62	64
65	49·06	42·64	48·87	42·86	48·68	43·07	48·49	43·28	65
66	49·81	43·30	49·62	43·52	49·43	43·73	49·24	43·95	66
67	50·57	43·96	50·37	44·18	50·18	44·40	49·99	44·61	67
68	51·32	44·61	51·13	44·84	50·93	45·06	50·73	45·28	68
69	52·07	45·27	51·88	45·49	51·68	45·72	51·48	45·95	69
70	52·83	45·92	52·63	46·15	52·43	46·38	52·22	46·61	70
71	53·58	46·58	53·38	46·81	53·18	47·05	52·97	47·28	71
72	54·34	47·24	54·13	47·47	53·92	47·71	53·72	47·94	72
73	55·09	47·89	54·88	48·13	54·67	48·37	54·46	48·61	73
74	55·85	48·55	55·64	48·79	55·42	49·03	55·21	49·28	74
75	56·60	49·20	56·39	49·45	56·17	49·70	55·95	49·94	75
76	57·36	49·86	57·14	50·11	56·92	50·36	56·70	50·61	76
77	58·11	50·52	57·89	50·77	57·67	51·02	57·45	51·27	77
78	58·87	51·17	58·64	51·43	58·42	51·68	58·19	51·94	78
79	59·62	51·83	59·40	52·09	59·17	52·35	58·94	52·60	79
80	60·38	52·48	60·15	52·75	59·92	53·01	59·68	53·27	80
81	61·13	53·14	60·90	53·41	60·67	53·67	60·43	53·94	81
82	61·89	53·80	61·65	54·07	61·41	54·33	61·18	54·60	82
83	62·64	54·45	62·40	54·73	62·16	55·00	61·92	55·27	83
84	63·40	55·11	63·15	55·38	62·91	55·66	62·67	55·93	84
85	64·15	55·76	63·91	56·04	63·66	56·32	63·41	56·60	85
86	64·90	56·42	64·66	56·70	64·41	56·99	64·16	57·27	86
87	65·66	57·08	65·41	57·36	65·16	57·65	64·91	57·93	87
88	66·41	57·73	66·16	58·02	65·91	58·31	65·65	58·60	88
89	67·17	58·39	66·91	58·68	66·66	58·97	66·40	59·26	89
90	67·92	59·05	67·67	59·34	67·41	59·64	67·15	59·93	90
91	68·68	59·70	68·42	60·00	68·15	60·30	67·89	60·60	91
92	69·43	60·36	69·17	60·66	68·90	60·96	68·64	61·26	92
93	70·19	61·01	69·92	61·32	69·65	61·62	69·38	61·93	93
94	70·94	61·67	70·67	61·98	70·40	62·29	70·13	62·59	94
95	71·70	62·33	71·43	62·64	71·15	62·95	70·88	63·26	95
96	72·45	62·98	72·18	63·30	71·90	63·61	71·62	63·92	96
97	73·21	63·64	72·93	63·96	72·65	64·27	72·37	64·59	97
98	73·96	64·29	73·68	64·62	73·40	64·94	73·11	65·26	98
99	74·72	64·95	74·43	65·28	74·15	65·60	73·86	65·92	99
100	75·47	65·61	75·18	65·93	74·90	66·26	74·61	66·59	100
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
Distance.	49 Deg.		48¾ Deg.		48½ Deg.		48¼ Deg.		Distance.

Distance.	42 Deg.		42¼ Deg.		42½ Deg.		42¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·74	0·67	0·74	0·67	0·74	0·68	0·73	0·68	1
2	1·49	1·34	1·48	1·34	1.47	1·35	1·47	1·36	2
3	2·23	2·01	2·22	2·02	2·21	2·03	2·20	2·04	3
4	2·97	2·68	2·96	2·69	2·95	2·70	2·94	2·72	4
5	3·72	3·35	3·70	3·36	3·69	3·38	3·67	3·39	5
6	4·46	4·01	4·44	4·03	4·42	4·05	4·41	4·07	6
7	5·20	4·68	5·18	4·71	5·16	4·73	5·14	4·75	7
8	5·95	5·35	5·92	5·38	5·90	5·40	5·87	5·43	8
9	6·69	6·02	6·66	6·05	6·64	6·08	6·61	6·11	9
10	7·43	6·69	7·40	6·72	7·37	6·76	7·34	6·79	10
11	8·17	7·36	8·14	7·40	8·11	7·43	8·08	7·47	11
12	8·92	8·03	8·88	8·07	8·85	8·11	8·81	8·15	12
13	9·66	8·70	9·62	8·74	9·58	8·78	9·55	8·82	13
14	10·40	9·37	10·36	9·41	10·32	9·46	10·28	9·50	14
15	11·15	10·04	11·10	10·09	11·06	10·13	11·01	10·18	15
16	11·89	10·71	11·84	10·76	11·80	10·81	11·75	10·86	16
17	12·63	11·38	12·58	11·43	12·53	11·48	12·48	11·54	17
18	13·38	12·04	13·32	12·10	13·27	12·16	13·22	12·22	18
19	14·12	12·71	14·06	12·77	14·01	12·84	13·95	12·90	19
20	14·86	13·38	14·80	13·45	14·75	13·51	14·69	13·58	20
21	15·61	14·05	15·54	14·12	15·48	14·19	15·42	14·25	21
22	16·35	14·72	16·28	14·79	16·22	14·86	16·16	14·93	22
23	17·09	15·39	17·02	15·46	16·96	15·54	16·89	15·61	23
24	17·84	16·06	17·77	16·14	17·69	16·21	17·62	16·29	24
25	18·58	16·73	18·51	16·81	18·43	16·89	18·36	16·97	25
26	19·32	17·40	19·25	17·48	19·17	17·57	19·09	17·65	26
27	20·06	18·07	19·99	18·15	19·91	18·24	19·83	18·33	27
28	20·81	18·74	20·73	18·83	20·64	18·92	20·56	19·01	28
29	21·55	19·40	21·47	19·50	21·38	19·59	21·30	19·69	29
30	22·29	20·07	22·21	20·17	22·12	20·27	22·03	20·36	30
31	23·04	20·74	22·95	20·84	22·86	20·94	22·76	21·04	31
32	23·78	21·41	23·69	21·52	23·59	21·62	23·50	21·72	32
33	24·52	22·08	24·43	22·19	24·33	22·29	24·23	22·40	33
34	25·27	22·75	25·17	22·86	25·07	22·97	24·97	23·08	34
35	26·01	23·42	25·91	23·53	25·80	23·65	25·70	23·76	35
36	26·75	24·09	26·65	24·21	26·54	24·32	26·44	24·44	36
37	27·50	24·76	27·39	24·88	27·28	25·00	27·17	25·12	37
38	28·24	25·43	28·13	25·55	28·02	25·67	27·90	25·79	38
39	28·98	26·10	28·87	26·22	28·75	26·35	28·64	26·47	39
40	29·73	26·77	29·61	26·89	29·49	27·02	29·37	27·15	40
41	30·47	27·43	30·35	27·57	30·23	27·70	30·11	27·83	41
42	31·21	28·10	31·09	28·24	30·97	28·37	30·84	28·51	42
43	31·96	28·77	31·83	28·91	31·70	29·05	31·58	29·19	43
44	32·70	29·44	32·57	29·58	32·44	29·73	32·31	29·87	44
45	33·44	30·11	33·31	30·26	33·18	30·40	33·04	30·55	45
46	34·18	30·78	34·05	30·93	33·91	31·08	33·78	31·22	46
47	34·93	31·45	34·79	31·60	34·65	31·75	34·51	31·90	47
48	35·67	32·12	35·53	32·27	35·39	32·43	35·25	32·58	48
49	36·41	32·79	36·27	32·95	36·13	33·10	35·98	33·26	49
50	37·16	33·46	37·01	33·62	36·86	33·78	36·72	33·94	50
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
Distance.	48 Deg.		47¾ Deg.		47½ Deg.		47¼ Deg.		Distance.

Distance.	42 Deg.		42¼ Deg.		42½ Deg.		42¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	37·90	34·13	37·75	34·29	37·60	34·46	37·45	34·62	51
52	38·64	34·79	38·49	34·96	38·34	35·13	38·18	35·30	52
53	39·39	35·46	39·23	35·64	39·08	35·81	38·92	35·98	53
54	40·13	36·13	39·97	36·31	39·81	36·48	39·65	36·66	54
55	40·87	36·80	40·71	36·98	40·55	37·16	40·39	37·33	55
56	41·62	37·47	41·45	37·65	41·29	37·83	41·12	38·01	56
57	42·36	38·14	42·19	38·32	42·02	38·51	41·86	38·69	57
58	43·10	38·81	42·93	39·00	42·76	39·18	42·59	39·37	58
59	43·85	39·48	43·67	39·67	43·50	39·86	43·32	40·05	59
60	44·59	40·15	44·41	40·34	44·24	40·54	44·06	40·73	60
61	45·33	40·82	45·15	41·01	44·97	41·21	44·79	41·41	61
62	46·07	41·49	45·89	41·69	45·71	41·89	45·53	42·09	62
63	46·82	42·16	46·63	42·36	46·45	42·56	46·26	42·76	63
64	47·56	42·82	47·37	43·03	47·19	43·24	47·00	43·44	64
65	48·30	43·49	48·11	43·70	47·92	43·91	47·73	44·12	65
66	49·05	44·16	48·85	44·38	48·66	44·59	48·47	44·80	66
67	49·79	44·83	49·59	45·05	49·40	45·26	49·20	45·48	67
68	50·53	45·50	50·33	45·72	50·13	45·94	49·93	46·16	68
69	51·28	46·17	51·07	46·39	50·87	46·62	50·67	46·84	69
70	52·02	46·84	51·82	47·07	51·61	47·29	51·40	47·52	70
71	52·76	47·51	52·56	47·74	52·35	47·97	52·14	48·19	71
72	53·51	48·18	53·30	48·41	53·08	48·64	52·87	48·87	72
73	54·25	48·85	54·04	49·08	53·82	49·32	53·61	49·55	73
74	54·99	49·52	54·78	49·76	54·56	49·99	54·34	50·23	74
75	55·74	50·18	55·52	50·48	55·30	50·67	55·07	50·91	75
76	56·48	50·85	56·26	51·10	56·03	51·34	55·81	51·59	76
77	57·22	51·52	57·00	51·77	56·77	52·02	56·54	52·27	77
78	57·97	52·19	57·74	52·44	57·51	52·70	57·28	52·95	78
79	58·71	52·86	58·48	53·12	58·24	53·37	58·01	53·63	79
80	59·45	53·53	59·22	53·79	58·98	54·05	58·75	54·30	80
81	60·19	54·20	59·96	54·46	59·72	54·72	59·48	54·98	81
82	60·94	54·87	60·70	55·13	60·46	55·40	60·21	55·66	82
83	61·68	55·54	61·44	55·81	61·19	56·07	60·95	56·34	83
84	62·42	56·21	62·18	56·48	61·93	56·75	61·68	57·02	84
85	63·17	56·88	62·92	57·15	62·67	57·43	62·42	57·70	85
86	62·91	57·55	63·66	57·82	63·41	58·10	63·15	58·38	86
87	64·65	58·21	64·40	58·50	64·14	58·78	63·89	59·06	87
88	65·40	58·88	65·14	59·17	64·88	59·45	64·62	59·73	88
89	66·14	59·55	65·88	59·84	65·62	60·13	65·35	60·41	89
90	66·88	60·22	66·62	60·51	66·35	60·80	66·09	61·09	90
91	67·63	60·89	67·36	61·19	67·09	61·48	66·82	61·77	91
92	68·37	61·56	68·10	61·86	67·83	62·15	67·56	62·45	92
93	69·11	62·23	68·84	62·53	68·57	62·83	68·29	63·13	93
94	69·86	62·90	69·58	63·20	69·30	63·51	69·03	63·81	94
95	70·60	63·57	70·32	63·87	70·04	64·18	69·76	64·49	95
96	71·34	64·24	71·06	64·55	70·78	64·86	70·49	65·16	96
97	72·08	64·91	71·80	65·22	71·52	65·53	71·23	65·84	97
98	72·83	65·57	72·54	65·89	72·25	66·21	71·96	66·52	98
99	73·57	66·24	73·28	66·56	72·99	66·88	72·70	67·20	99
100	74·31	66·91	74·02	67·24	73·73	67·56	73·43	67·88	100
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	
Distance.	48 Deg.		47¾ Deg.		47½ Deg.		47¼ Deg.		Distance.

Distance.	43 Deg.		43¼ Deg.		43½ Deg.		43¾ Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·73	0·68	0·73	0·69	0·73	0·69	0·72	0·69	1
2	1·46	1·36	1·46	1·37	1·45	1·38	1·44	1·38	2
3	2·19	2·05	2·19	2·06	2·18	2·07	2·17	2·07	3
4	2·93	2·73	2·91	2·74	2·90	2·75	2·89	2·77	4
5	3·66	3·41	3·64	3·43	3·63	3·44	3·61	3·46	5
6	4·39	4·09	4·37	4·11	4·35	4·13	4·33	4·15	6
7	5·12	4·77	5·10	4·80	5·08	4·82	5·06	4·84	7
8	5·85	5·46	5·83	5·48	5·80	5·51	5·78	5·53	8
9	6·58	6·14	6·56	6·17	6·53	6·20	6·50	6·22	9
10	7·31	6·82	7·28	6·85	7·25	6·88	7·22	6·92	10
11	8·04	7·50	8·01	7·54	7·98	7·57	7·95	7·61	11
12	8·78	8·18	8·74	8·22	8·70	8·26	8·67	8·30	12
13	9·51	8·87	9·47	8·91	9·43	8·95	9·39	8·99	13
14	10·24	9·55	10·20	9·59	10·16	9·64	10·11	9·68	14
15	10·97	10·23	10·93	10·28	10·88	10·33	10·84	10·37	15
16	11·70	10·91	11·65	10·96	11·61	11·01	11·56	11·06	16
17	12·43	11·59	12·38	11·65	12·33	11·70	12·28	11·76	17
18	13·16	12·28	13·11	12·33	13·06	12·39	13·00	12·45	18
19	13·90	12·96	13·84	13·02	13·78	13·08	13·72	13·14	19
20	14·63	13·64	14·57	13·70	14·51	13·77	14·45	13·83	20
21	15·36	14·32	15·30	14·39	15·23	14·46	15·17	14·52	21
22	16·09	15·00	16·02	15·07	15·96	15·14	15·89	15·21	22
23	16·82	15·60	16·75	15·76	16·68	15·83	16·51	15·90	23
24	17·55	16·37	17·48	16·44	17·41	16·52	17·34	16·60	24
25	18·28	17·05	18·21	17·13	18·13	17·21	18·06	17·29	25
26	19·02	17·73	18·94	17·81	18·86	17·90	18·78	17·98	26
27	19·75	18·41	19·67	18·50	19·59	18·59	19·50	18·67	27
28	20·48	19·10	20·39	19·19	20·31	19·27	20·23	19·36	28
29	21·21	19·78	21·12	19·87	21·04	19·96	20·95	20·05	29
30	21·94	20·46	21·85	20·56	21·76	20·65	21·67	20·75	30
31	22·67	21·14	22·58	21·24	22·49	21·34	22·39	21·44	31
32	23·40	21·82	23·31	21·93	23·21	22·03	23·12	22·13	32
33	24·13	22·51	24·04	22·61	23·94	22·72	23·84	22·82	33
34	24·87	23·19	24·76	23·30	24·66	23·40	24·56	23·51	34
35	25·60	23·87	25·49	23·98	25·39	24·09	25·28	24·20	35
36	26·33	24·55	26·22	24·67	26·11	24·78	26·01	24·89	36
37	27·06	25.23	26·95	25·35	26·84	25·47	26·73	25·59	37
38	27·79	25·92	27·68	26·04	27·56	26·16	27·45	26·28	38
39	28·52	26·60	28·41	26·72	28·29	26·85	28·17	26·97	39
40	29·25	27·28	29·13	27·41	29·01	27·53	28·89	27·66	40
41	29·99	27·96	29·86	28·09	29·74	28·22	29·62	28·35	41
42	30·72	28·64	30·59	28·78	30·47	28·91	30·34	29·04	42
43	31·45	29·33	31·32	29·46	31·19	29·60	31·06	29·74	43
44	32·18	30·01	32·05	30·15	31·92	30·29	31·78	30·43	44
45	32·91	30·69	32·78	30·83	32·64	30·98	32·51	31·12	45
46	33·64	31·37	33·51	31·52	33·37	31·66	33·23	31·81	46
47	34·37	32·05	34·23	32·20	34·09	32·35	33·95	32·50	47
48	35·10	32·74	34·96	32·89	34·82	33·04	34·67	33·19	48
49	35·84	33·42	35·69	33·57	35·54	33·73	35·40	33·88	49
50	36·57	34·10	36·42	34·26	36·27	34·42	36·12	34·58	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	47 Deg.		46¾ Deg.		46½ Deg.		46¼ Deg.		

Distance.	43 Deg. Lat.	43 Deg. Dep.	43¼ Deg. Lat.	43¼ Deg. Dep.	43½ Deg. Lat.	43½ Deg. Dep.	43¾ Deg. Lat.	43¾ Deg. Dep.	Distance.
51	37·30	34·78	37·15	34·94	36·99	35·11	36·84	35·27	51
52	38·03	35·46	37·88	35·63	37·72	35·79	37·56	35·96	52
53	38·67	36·15	38·60	36·31	38·44	36·48	38·29	36·65	53
54	39·49	36·83	39·33	37·00	39·17	37·17	39·01	37·34	54
55	40·22	37·51	40·06	37·69	39·90	37·86	39·73	38·03	55
56	40·96	38·19	40·79	38·37	40·62	38·55	40·45	38·72	56
57	41·69	38·87	41·52	39·06	41·35	39·24	41·17	39·42	57
58	42·42	39·56	42·25	39·74	42·07	39·92	41·90	40·11	58
59	43·15	40·24	42·97	40·43	42·80	40·61	42·62	40·80	59
60	43·88	40·92	43·70	41·11	43·52	41·30	43·34	41·49	60
61	44·61	41·60	44·43	41·80	44·25	41·99	44·06	42·18	61
62	45·34	42·28	45·16	42·48	44·97	42·68	44·79	42 87	62
63	46·08	42·97	45·89	43·17	45·70	43·37	45·51	43·57	63
64	46·81	43·65	46·62	43·85	46·42	44·05	46·23	44·26	64
65	47·54	44·33	47·34	44·54	47·15	44·74	46·95	44·95	65
66	48·27	45·01	48·07	45·22	47·87	45·43	47·68	45·64	66
67	49·00	45·69	48·80	45·91	48·60	46·12	48·40	46·33	67
68	49·73	46·38	49·53	46·59	49·33	46·81	49·12	47·02	68
69	50·56	47·06	50·26	47·28	50·05	47·50	49·84	47·71	69
70	51·19	47·74	50·99	47·96	50·78	48·18	50·57	48·41	70
71	51·93	48·42	51·71	48·65	51·50	48·87	51·29	49·10	71
72	52·66	49·10	52·44	49·33	52·23	49·56	52·01	49·79	72
73	53·39	49·79	53·17	50·02	52·95	50·25	52·73	50·48	73
74	54·12	50·47	53·90	50·70	53·68	50 94	53·45	51·17	74
75	54·85	51·15	54·63	51·39	54·40	51·63	54·18	51·86	75
76	55·58	51·83	55·36	52·07	55·13	52·31	54·90	52·55	76
77	56·31	52·51	56·08	52·76	55·85	53·00	55·62	53·25	77
78	57·05	53·20	56·81	53·44	56·58	53·69	56·34	53·94	78
79	57·78	53·88	57·54	54·13	57·30	54·38	57·07	54·63	79
80	58·51	54·56	58·27	54·81	58·03	55·07	57·79	55·32	80
81	59·24	55·24	59·00	55·50	58·76	55·76	58·51	56·01	81
82	59·97	55·92	59·73	56·18	59·48	56·45	59·23	56·70	82
83	60·70	56·61	60·45	56·87	60·21	57·13	59·96	57·40	83
84	61·43	57·29	61·18	57·56	60·93	57·82	60·68	58·09	84
85	62·17	57·97	61·91	58·24	61·66	58·51	61·40	58·78	85
86	62·90	58·65	62·64	58·93	62·38	59·20	62·12	59·47	86
87	63·63	59·33	63·37	59·61	63·11	59·89	62·85	60·16	87
88	64·36	60·02	64·10	60·30	63·83	60·58	63·57	60·85	88
89	65·09	60·70	64·82	60·98	64·56	61·26	64·29	61·54	89
90	65·82	61·38	65·55	61·67	65·28	61·95	65·01	62·24	90
91	66·55	62·06	66·28	62·35	66·01	62·64	65·74	62·93	91
92	67·28	62·74	67·01	63·04	66·73	63·33	66·46	63·62	92
93	68·02	63·43	67·74	63·72	67 46	64·02	67·18	64·31	93
94	68·75	64·11	68·47	64·41	68·19	64·71	67·90	65·00	94
95	69·48	64·79	69·20	65·09	68·91	65·39	68·62	65·69	95
96	70·21	65·47	69·92	65·78	69·64	66·08	69·35	66·39	96
97	70·94	66·15	70·65	66·46	70·36	66·77	70·07	67·08	97
98	71·67	66·84	71·37	67·15	71·09	67·46	60·79	67·77	98
99	72·40	67·52	72·11	67·83	71·81	68·15	71·51	68·46	99
100	73·14	68·20	72·84	68·52	72·54	68·84	72·24	69·15	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	47 Deg.		46¾ Deg.		46½ Deg.		46¼ Deg.		

Distance.	44 Deg.		44¼ Deg.		44½ Deg.		44¾ Deg.		45 Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
1	0·72	0·69	0·72	0·70	0·71	0·70	0·71	0·71	0·71	0.71	1
2	1·44	1·39	1·43	1·40	1·43	1·40	1·42	1·41	1·41	1.41	2
3	2·16	2·08	2·15	2·09	2·14	2·10	2·13	2·11	2·12	2·12	3
4	2·88	2·78	2·87	2·79	2·85	2·80	2·84	2·82	2·83	2·83	4
5	3·60	3·47	3·58	3·49	3·57	3·50	3·55	3·52	3·54	3·54	5
6	4·32	4·17	4·30	4·19	4·28	4·21	4·26	4·22	4·24	4·24	6
7	5·04	4·86	5·01	4·88	4·99	4·91	4·97	4·93	4·95	4·95	7
8	5·75	5·56	5·73	5·58	5·71	5·61	5·68	5·63	5·66	5·66	8
9	6·47	6·25	6·45	6·28	6·42	6·31	6·39	6·34	6·36	6·36	9
10	7·19	6·95	7·16	6·98	7·13	7·01	7·10	7·04	7·07	7·07	10
11	7·91	7·64	7·88	7·68	7·85	7·71	7·81	7·74	7·78	7·78	11
12	8·63	8·34	8·60	8·37	8·56	8·41	8·52	8·45	8·49	8·49	12
13	9·35	9·03	9·31	9·07	9·27	9·11	9·23	9·15	9·19	9·19	13
14	10·07	9·73	10·03	9·77	9·99	9·81	9·94	9·86	9·90	9·90	14
15	10·79	10·42	10·74	10·47	10·70	10·51	10·65	10·56	10·61	10·61	15
16	11·51	11·11	11·46	11·16	11·41	11·21	11·36	11·26	11·31	11·31	16
17	12·23	11·81	12·18	11·86	12·13	11·92	12·07	11·97	12·02	12·02	17
18	12·95	12·50	12·89	12·56	12·84	12·62	12·78	12·67	12·73	12·73	18
19	13·67	13·20	13·61	13·26	13·55	13·32	13·49	13·38	13·43	13·43	19
20	14·39	13·89	14·33	13·96	14·26	14·02	14·20	14·08	14·14	14·14	20
21	15·11	14·59	15·04	14·65	14·98	14·72	14·91	14·78	14·85	14·85	21
22	15.83	15·28	15·76	15·35	15·69	15·42	15·62	15·49	15·56	15·56	22
23	16·54	15·98	16·47	16·05	16·40	16·12	16·33	16·19	16·26	16·26	23
24	17·26	16·67	17·19	16·75	17·12	16·82	17·04	16·90	16·97	16·97	24
25	17·98	17·37	17·91	17·44	17·83	17·52	17·75	17·60	17·68	17·68	25
26	18·70	18·06	18·62	18·14	18·54	18·22	18·46	18·30	18·38	18·38	26
27	19·42	18·76	19·34	18·84	19·26	18·92	19·17	19·01	19·09	19·09	27
28	20·14	19·45	20·06	19·54	19·97	19·63	19·89	19·71	19·80	19·80	28
29	20·86	20·15	20·77	20·24	20·68	20·33	20·60	20·52	20·51	20·51	29
30	21·58	20·84	21·49	20·93	21·40	21·03	21·31	21·12	21·21	21·21	30
31	22·30	21·53	22·21	21·63	22·11	21·73	22·02	21·82	21·92	21·92	31
32	23·02	22·23	22·92	22·33	22·82	22·43	22·73	22·53	22·63	22·63	32
33	23·74	22·92	23·64	23·03	23·54	23·13	23·44	23·23	23·33	23·33	33
34	24·46	23·62	24·35	23·72	24·25	23·83	24·15	23·94	24·04	24·02	34
35	25·18	24·31	25·07	24·42	24·96	24·53	24·86	24·64	24·75	24·75	35
36	25·90	25·01	25·79	25·12	25·68	25·23	25·57	25·34	25·46	25·46	36
37	26·62	25·70	26·50	25·82	26·39	25·93	26·28	26·05	26·16	26·16	37
38	27·33	26·40	27·22	26·52	27·10	26·63	26·99	26·75	26·87	26·87	38
39	28·05	27·09	27·94	27·21	27·82	27·34	27·70	27·46	27·58	27·58	39
40	28·77	27·79	28·65	27·91	28·53	28·04	28·41	28·16	28·28	28·28	40
41	29·49	28·48	29·37	28·61	29·24	28·74	29·12	28·86	28·99	28·99	41
42	30·21	29·18	30·08	29·31	29·96	29·44	29·83	28·57	29·70	29·70	42
43	30·93	29·87	30·80	30·00	30·67	30·14	30·54	30·27	30·41	30·41	43
44	31·65	30·56	31·52	30·70	31·38	30·84	31·25	30·98	31·11	31·11	44
45	32·37	31·26	32·23	31·40	32·10	31·54	31·96	31·68	31·82	31·82	45
46	33·09	31·95	32·95	32·10	32·81	32·24	32·67	32·38	32·53	32·53	46
47	33·81	32·65	33·67	22·80	33·52	32·94	33·38	33·09	33·23	33·23	47
48	34·53	33·34	34·38	33·49	34·24	33·64	34·09	33·79	33·94	33·94	48
49	35·25	34·04	35·10	34·19	34·95	34·34	34·80	34·50	34·65	34·65	49
50	35·97	34·73	35·82	34·89	35·66	35·05	35·51	35·20	35·36	35·36	50
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	46 Deg.		45¾ Deg.		45½ Deg.		45¼ Deg.		45 Deg.		

Distance.	44 Deg.		44¼ Deg.		44½ Deg.		44¾ Deg.		45 Deg.		Distance.
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	
51	36·69	35·43	36·53	35·59	36·38	35·75	36·22	35·90	36·06	36·06	51
52	37·41	36·12	37·25	36·29	37·09	36·45	36·93	36·61	36·77	36·77	52
53	38·12	36·82	37·96	36·98	37·80	37·15	37·64	37·31	37·48	37·48	53
54	38·84	37·51	38·68	37·68	38·52	37·85	38·35	38·02	38·18	38·18	54
55	39·56	38·21	39·40	38·38	39·23	38·55	39·06	38·72	38·89	38·89	55
56	40·28	38·90	40·11	39·08	39·94	39·25	39·77	39·42	39·60	39·60	56
57	41·00	39·60	40·83	39·77	40·66	39·95	40·48	40·13	40·31	40·31	57
58	41·72	40·29	41·55	40·47	41·37	40·65	41·19	40·83	41·01	41·01	58
59	42·44	40·98	42·26	41·17	42·08	41·35	41·90	41·54	41·72	41·72	59
60	43·16	41·68	42·98	41·87	42·79	42·05	42·61	42·24	42·43	42·43	60
61	43·88	42·37	43·69	42·57	43·51	42·76	43·32	42·94	43·13	43·13	61
62	44·60	43·07	44·41	43·26	44·22	43·46	44·03	43·65	43·84	43·84	62
63	45·32	43·76	45·13	43·96	44·93	44·16	44·74	44·35	44·55	44·55	63
64	46·04	44·46	45·84	44·66	45·65	44·86	45·45	45·06	45·25	45·25	64
65	46·76	45·15	46·56	45·36	46·36	45·56	46·16	45·76	45·96	45·96	65
66	47·48	45·85	47·28	46·05	47·07	46·26	46·87	46·46	46·67	46·67	66
67	48·20	46·54	47·99	46·75	47·79	46·96	47·58	47·17	47·38	47·38	67
68	48·92	47·24	48·71	47·45	48·50	47·66	48·29	47·87	48·08	48·08	68
69	49·63	47·93	49·42	48·15	49·21	48·36	49·00	48·58	48·79	48·79	69
70	50·35	48·63	50·14	48·85	49·93	49·06	49·71	49·28	49·50	49·50	70
71	51·07	49·32	50·86	49·54	50·64	49·76	50·42	49·98	50·20	50·20	71
72	51·79	50·02	51·57	50·24	51·35	50·47	51·13	50·69	50·91	50·91	72
73	52·51	50·71	52·29	50·94	52·07	51·17	51·84	51·39	51·62	51·62	73
74	53·23	51·40	53·01	51·64	52·78	51·87	52·55	52·10	52·33	52·33	74
75	53·95	52·10	53·72	52·33	53·49	52·57	53·26	53·80	53·03	53·03	75
76	54·67	52·79	54·44	53·03	54·21	53·27	53·97	53·51	53·74	53·74	76
77	55·39	53·49	55·16	53·73	54·92	53·97	54·68	54·21	54·45	54·45	77
78	56·11	54·18	55.87	54·43	55·63	54·67	55·39	54·91	55·15	55·15	78
79	56·83	54·88	56·59	55·13	56·35	55·37	56·10	55·62	55·86	55·86	79
80	57·55	55·57	57·30	55·82	57·06	56·07	56·81	56·32	56·57	56·57	80
81	58·27	56·27	58·02	56·52	57·77	56·77	57·52	57·03	57·28	57·28	81
82	58·99	56·96	58·74	57·22	58·49	57·47	58·24	57.73	57·98	57·98	82
83	59·71	57·56	59·45	57·92	59·20	58·18	58·95	58·43	58·69	58·69	83
84	60·42	58·35	60·17	58·61	59·91	58·88	59·66	59·14	59·40	59·40	84
85	61·14	59·05	60·89	59·31	60·63	59·58	60·37	59·84	60·10	60·10	85
86	61·86	59·74	61·60	60·01	61·34	60·28	61·08	60·55	60·81	60·81	86
87	62·58	60·44	62·32	60·71	62·05	60·98	61·79	61·25	61·52	61·52	87
88	63·30	61·13	63·03	61·41	62·77	61·68	62·50	61·95	62·23	62·23	88
89	64·02	61·82	63·75	62·10	63·48	62·38	63·21	62·66	62·93	62·93	89
90	64·74	62·52	64·47	62·80	64·19	63·08	63·92	63·36	63·64	63·64	90
91	65·46	63·21	65·18	63·50	64·91	63·78	64·63	64·07	64·35	64·35	91
92	66·18	63·91	65·90	64·20	65·62	64·48	65·34	64·77	65·05	65·05	92
93	66·90	64·60	66·62	64·89	66·33	65·18	66·05	65·47	65·76	65·76	93
94	67·62	65·30	67·33	65·59	67·05	65·89	66·76	66·18	66·47	66·47	94
95	68·34	65·99	68·05	66·29	67·76	66·59	67·47	66·88	67·18	67·18	95
96	69·06	66·69	68·76	66·99	68·47	67·29	68·18	67·59	67·88	67·88	96
97	69·78	67·38	69·48	67·69	69·19	67·99	68·89	68·29	68·59	68·59	97
98	70·50	68·08	70·20	68·38	69·90	68·69	69·60	68·99	69·30	69·30	98
99	71·21	68·77	70·91	69·08	70·61	60·39	70·31	69·70	70·00	70·00	99
100	71·93	69·47	71·63	69·78	71·33	70·09	71·02	70·40	70·71	70·71	100
Distance.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Distance.
	46 Deg.		45¾ Deg.		45½ Deg.		45¼ Deg.		45 Deg.		

SQUARES, CUBES, SQUARE AND CUBE ROOTS OF NUMBERS.

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
1	1	1	1·0000000	1·0000000	·100000000
2	4	8	1·4142136	1·2599210	·500000000
3	9	27	1·7320508	1·4422496	·333333333
4	16	64	2·0000000	1·5874011	·250000000
5	25	125	2·2360680	1·7099759	·200000000
6	36	216	2·4494897	1·8171206	·166666667
7	49	343	2·6457513	1·9129312	·142857143
8	64	512	2·8284271	2·0000000	·125000000
9	81	729	3·0000000	2·0800837	·111111111
10	100	1000	3·1622777	2·1544347	·100000000
11	121	1331	3·3166248	2·2239801	·090909091
12	144	1728	3·4641016	2·2894286	·083333333
13	169	2197	3·6055513	2·3513347	·076923077
14	196	2744	3·7416574	2·4101422	·071428571
15	225	3375	3·8729833	2·4662121	·066666667
16	256	4096	4·0000000	2·5198421	·062500000
17	289	4913	4·1231056	2·5712816	·058823529
18	324	5832	4·2426407	3·6207414	·055555556
19	361	6859	4·3588989	2·6684016	·052631579
20	400	8000	4·4721360	2·7144177	·050000000
21	441	9261	4·5825757	2·7589243	·047619048
22	484	10648	4·6904158	2·8020393	·045454545
23	529	12167	4·7958315	2·8438670	·043478261
24	576	13824	4·8989795	2·8844991	·041666667
25	625	15625	5·0000000	2·9240177	·040000000
26	676	17576	5·0990195	2·9624960	·038461538
27	729	19683	5·1961524	3·0000000	·037037037
28	784	21952	5·2915026	3·0365889	·035714286
29	841	24389	5·3851648	3·0723168	·034482759
30	900	27000	5·4772256	3·1072325	·033333333
31	961	29791	5·5677644	3·1413806	·032258065
32	1024	32768	5·6568542	3·1748021	·031250000
33	1089	35937	5·7445626	3·2075343	·030303030
34	1156	39304	5·8309519	3·2396118	·029411765
35	1225	42875	5·9160798	3·2716663	·028571429
36	1296	46656	6·0000000	3·3019272	·027777778
37	1369	50653	6·0827625	3·3322218	·027027027
38	1444	54872	6·1644140	3·3619754	·026315789
39	1521	59319	6·2449980	3·3912114	·025641026
40	1600	64000	6·3245553	3·4199519	·025000000
41	1681	68921	6·4031242	3·4482172	·024390244
42	1764	74088	6·4807407	3·4760266	·023809524
43	1849	79507	6·5574385	3·5033981	·023255814
44	1936	85184	6·6332496	3·5303483	·022727273
45	2025	91125	6·7082039	3·5568933	·022222222
46	2116	97336	6·7823300	3·5830479	·021739130
47	2209	103823	6·8556546	3·6088261	·021276600
48	2304	110592	6·9282032	3·6342411	·020833333
49	2401	117649	7·0000000	3·6593057	·020408163
50	2500	125000	7·0710678	3·6840314	·020000000

Nos	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
1	2601	132651	7·1414284	3·7084298	·019607843
52	2704	140608	7·2111026	3·7325111	·019230769
53	2809	148877	7·2801099	3·7562858	·018867925
54	2916	157464	7·3484692	3·7797631	·018518519
55	3025	166375	7·4161985	3·8029525	·018181818
56	3136	175616	7·4833148	3·8258624	·017857143
57	3249	185193	7·5498344	3·8485011	·017543860
58	3364	195112	7·6157731	3·8708766	·017241379
59	3481	205379	7·6811457	3·8929965	·016949153
60	3600	216000	7·7459667	3·9148676	·016666667
61	3721	226981	7·8102497	3·9364972	·016393443
62	3844	238328	7·8740079	3·9578915	·016129032
63	3969	250047	7·9372539	3·9790571	·015873016
64	4096	262144	8·0000000	4·0000000	·015625000
65	4225	274625	8·0622577	4·0207256	·015384615
66	4356	287496	8·1240384	4·0412401	·015151515
67	4489	300763	8·1853528	4·0615480	·014925373
68	4624	314432	8·2462113	4·0816551	·014705882
69	4761	328509	8·3066239	4·1015661	·014492754
70	4900	343000	8·3666003	4·1212853	·014285714
71	5041	357911	8·4261498	4·1408178	·014084517
72	5184	373248	8·4852814	4·1601676	·013888889
73	5329	389017	8·5440037	4·1793390	·013698630
74	5476	405224	8·6023253	4·1983364	·013513514
75	5625	421875	8·6602540	4·2171633	·013333333
76	5776	438976	8·7177979	4·2358236	·013157895
77	5929	456533	8·7749644	4·2543210	·012987013
78	6084	474552	8·8317609	4·2726586	·012820513
79	6241	493039	8·8881944	4·2908404	·012658228
80	6400	512000	8·9442719	4·3088695	·012500000
81	6561	531441	9·0000000	4·3267487	·012345679
82	6724	551368	9·0553851	4·3444815	·012195122
83	6889	571787	9·1104336	4·3620707	·012048193
84	7056	592704	9·1651514	4·3795191	·011904762
85	7225	614125	9·2195445	4·3968296	·011764706
86	7396	636056	9·2736185	4·4140049	·011627907
87	7569	658503	9·3273791	4·4310476	·011494253
88	7744	681472	9·3808315	4·4479692	·011363636
89	7921	704969	9·4339811	4·4647451	·011235955
90	8100	729000	9·4868330	4·4814047	·011111111
91	8281	753571	9·5393920	4·4979414	·010989011
92	8464	778688	9·5916630	4·5143574	·010869565
93	8649	804357	9·6436508	4·5306549	·010752688
94	8836	830584	9·6953597	4·5468359	·010638298
95	9025	857375	9·7467943	4·5629026	·010526316
96	9216	884736	9·7979590	4·5788570	·010416667
97	9409	912673	9·8488578	4·5947009	·010309278
98	9604	941192	9·8994949	4·6104363	·010204082
99	9801	970299	9·9498744	4·6260650	·010101010
100	10000	1000000	10·0000000	4·6415888	·010000000
101	10201	1030301	10·0498756	4·6570095	·009900990
102	10404	1061208	10·0995049	4·6723287	·009803922
103	10609	1092727	10·1488916	4·6875482	·009708738
104	10816	1124864	10·1980390	4·7026694	·009615385
105	11025	1157625	10·2469508	4·7176940	·009523810
106	11236	1191016	10·2956301	4·7326235	·009433962
107	11449	1225043	10·3440804	4·7474594	·009345794
108	11664	1259712	10·3923048	4·7622032	·009259259
109	11881	1295029	10·4403065	4·7768562	·009174312
110	12100	1331000	10·4880885	4·7914199	·009090909
111	12321	1367631	10·5356538	4·8058995	·009009009
112	12544	1404928	10·5830052	4·8202845	·008928571

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
113	12769	1442897	10·6301458	4·8345881	·008849558
114	12996	1481544	10·6770783	4·8488076	·008771930
115	13225	1520875	10·7238053	4·8629442	·008695652
116	13456	1560896	10·7703296	3·8769990	·008020690
117	13689	1601613	10·8166538	4·8909732	·008547009
118	13924	1643032	10·8627805	4·9048681	·008474576
119	14161	1685159	10·9087121	4·9186847	·008403361
120	14400	1728000	10·9544512	5·9324242	·008333333
121	14641	1771561	11·0000000	4·9460874	·008264463
122	14834	1815848	11·0453610	4·9596757	·008196721
123	15129	1860867	11·0905365	4·9731898	·008130081
124	15376	1906624	11·1355287	4·9866310	·008064516
125	15625	1953125	11·1803399	5·0000000	·008000000
126	15876	2000376	11·2249722	5·0132979	·007936508
127	16129	2048383	11·2694277	5·0265257	·007874016
128	16384	2097152	11·3137085	5·0396842	·007812500
129	16641	2146689	11·3578167	5·0527743	·007751938
130	16900	2197000	11·4017543	5·0657970	·007692308
131	17161	2248091	11·4455231	5·0787531	·007633588
132	17424	2299968	11·4891253	5·0916434	·007575758
133	17689	2352637	11·5325626	5·1044687	·007518797
134	17956	2406104	11·5758369	5·1172299	·007462687
135	18225	2460375	11·6189500	5·1299278	·007407407
136	18496	2515456	11·6619038	5·1425632	·007352941
137	18769	2571353	11·7046999	5·1551367	·007299270
138	19044	2628072	11·7473444	5·1676493	·007246377
139	19321	2685619	11·7898261	5·1801015	·007194245
140	19600	2744000	11·8321596	5·1924941	·007142857
141	19881	2803221	11·8743421	5·2048279	·007092199
142	20164	2863288	11·9163753	5·2171034	·007042254
143	20449	2924207	11·9582607	5·2293215	·006993007
144	20736	2985984	12·0000000	5·2414828	·006944444
145	21025	3048625	12·0415946	5·2535879	·006896552
146	21316	3112136	12·0830460	5·2656474	·006849315
147	21609	3176523	12·1243557	5·2776321	·006802721
148	21904	3241792	12·1655251	5·2895725	·006756757
149	22201	3307949	12·2065556	5·3014592	·006711409
150	22500	3375000	12·2474487	5·3132928	·006666667
151	22801	3442951	12·2882057	5·3250740	·006622517
152	23104	3511008	12·3288280	5·3368033	·006578947
153	23409	3581577	12·3693169	5·3484812	·006535948
154	23716	3652264	12·4096736	5·3601084	·006493506
155	24025	3723875	12·4498996	5·3716854	·006451613
156	24336	3796416	12·4899960	5·3832126	·006410256
157	24649	3869893	12·5299641	5·3946907	·006369427
158	24964	3944312	12·5698051	5·4061202	·006329114
159	25281	4019679	12·6095202	5·4175015	·006289308
160	25600	4096000	12·6491106	5·4288352	·006250000
161	25921	4173281	12·6885775	5·4401218	·006211180
162	26244	4251528	12·7279221	5·4513618	·006172840
163	26569	4330747	12·7671453	5·4625556	·006134969
164	26896	4410944	12·8062485	5·4737037	·006097561
165	27225	4492125	12·8452326	5·4848066	·006060606
166	27556	4574296	12·8840987	5·4958647	·006024096
167	27889	4657463	12·9228480	5·5068784	·005988024
168	28224	4741632	12·9614814	5·5178484	·005952381
169	28561	4826809	13·0000000	5·5287748	·005917160
170	28900	4913000	13·9384048	5·5396583	·005882353
171	29241	5000211	13·0766968	5·5504991	·005847953
172	29584	5088448	13·1148770	5·5612978	·005813953
173	29929	5177717	13·1529464	5·5720546	·005780347
174	30276	5268024	13·1909060	5·5827702	·005747126

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
175	30625	5359375	13·2287566	5·5934447	·005714286
176	30976	5451776	13·2664992	5·6040787	·005681818
177	31329	5545233	13·3041347	5·6146724	·005649718
178	31684	5639752	13·3416641	5·6252263	·005617978
179	32041	5735339	13·3790882	5·6357408	·005586592
180	32400	5832000	13·4164079	5·6462162	·005555556
181	32761	5929741	13·4536240	5·6566528	·005524862
182	33124	6028568	13·4907376	5·6670511	·005494505
183	33489	6128487	13·5277493	5·6774114	·005464481
184	32856	6229504	13·5646600	5·6877340	·005434783
185	34225	6331625	13·6014705	5·6980192	·005405405
186	34596	6434856	13·6381817	5·7082675	·005376344
187	34969	6539203	13·6747943	5·7184791	·005347594
188	35344	6644672	13·7113092	5·7286543	·005319149
189	35721	6751269	13·7477271	5·7387936	·005291005
190	36100	6859000	13·7840488	5·7488971	·005263158
191	36481	6967871	13·8202750	5·7589652	·005235602
192	26864	7077888	13·8564065	5·7689982	·005208333
193	37249	7189017	13·8924440	5·7789966	·005181347
194	37636	7301384	13·9283883	5·7889604	·005154639
195	38025	7414875	13·9642400	5·7988900	·005128205
196	38416	7529536	14·0000000	5·8087857	·005102041
197	38809	7645373	14·0356688	5·8186479	·005076142
198	39204	7762392	14·0712473	5·8284767	·005050505
199	39601	7880599	14·1067360	5·8382725	·005025126
200	40000	8000000	14·1421356	5·8480355	·005000000
201	40401	8120601	14·1774469	5·8577660	·004975124
202	40804	8242408	14·2126704	5·8674643	·004950495
203	41209	8365427	14·2478068	5·8771307	·004926108
204	41616	8489664	14·2828569	5·8867653	·004901961
205	42025	8615125	14·3178211	5·8963685	·004878049
206	42436	8741816	14·3527001	5·9059406	·004854369
207	42849	8869743	14·3874946	5·9154817	·004830918
208	43264	8998912	14·4222051	5·9249921	·004807692
209	43681	9129329	14·4568323	5·9344721	·004784689
210	44100	9261000	14·4913767	5·9439220	·004761905
211	44521	9393931	14·5258390	5·9533418	·004739336
212	44944	9528128	14·5602198	5·9627320	·004716981
213	45369	9663597	14·5945195	5·9720926	·004694836
214	45796	9800344	14·6287388	5·9814240	·004672897
215	46225	9938375	14·6628783	5·9907264	·004651163
216	46656	10077696	14·6969385	6·0000000	·004629630
217	47089	10218313	14·7309199	6·0092450	·004608295
218	47524	10360232	14·7648231	6·0184617	·004587156
219	47961	10503459	14·7986486	6·0276502	·004566210
220	48400	10648000	14·8323970	6·0368107	·004545455
221	48841	10793861	14·8660687	6·0459435	·004524887
222	49284	10941048	14·8996644	6·0550489	·004504505
223	49729	11089567	14·9331845	6·0641270	·004484305
224	50176	11239424	14·9666295	6·0731779	·004464286
225	50625	11390625	15·0000000	6·0822020	·004444444
226	51076	11543176	15·0332964	6·0911994	·004424779
227	51529	11697083	15·0665192	6·1001702	·004405286
228	51984	11852352	15·0996689	6·1091147	·004385965
229	52441	12008989	15·1327460	6·1180332	·004366812
230	52900	12167000	15·1657509	5·1269257	·004347826
231	53361	12326391	15·1986842	6·1357924	·004329004
232	53824	12487168	15·2315462	6·1446337	·004310345
233	54289	12649337	15·2643375	6·1534495	·004291845
234	54756	12812904	15·2970585	6·1622401	·004273504
235	55225	12977875	15·3297097	6·1710058	·004255319
236	55696	13144256	15·3622915	6·1797466	·004237288

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
237	56169	13312053	15·3948043	6·1884628	·004219409
238	56644	13481272	15·4272486	6·1671544	·004201681
239	57121	13651919	15·4596248	6·2058218	·004184100
240	57600	13824000	15·4919334	6·2144650	·004166667
241	58081	13997521	15·5241747	6·2230843	·004149378
242	58564	14172488	15·5563492	6·2316797	·004132231
243	59049	14348907	15·5884573	6·2402515	·004115226
244	59536	14526784	15·6204994	6·2487998	·004098361
245	60025	14706125	15·6524758	6·2573248	·004081633
246	60516	14886936	15·6843871	6·2658266	·004065041
247	61009	15069223	15·7162336	6·2743054	·004048583
248	61504	15252992	15·7480157	6·2827613	·004032258
249	62001	15438249	15·7797338	6·2911946	·004016064
250	62500	15625000	15·8113883	6·2996053	·004000000
251	63001	15813251	15·8429795	6·3079935	·003984064
252	63504	16003008	15·8745079	6·3163596	·003968254
253	64009	16194277	15·9059737	6·3247035	·003952569
254	64516	16387064	15·9373775	6·3330256	·003937008
255	65025	16581375	15·9687194	6·3413257	·003921569
256	65536	16777216	16·0000000	6·3496042	·003906250
257	66049	16974593	16·0312195	6·3578611	·003891051
258	66564	17173512	16·0623784	6·3660968	·003875969
259	67081	17373979	16·0934769	6·3743111	·003861004
260	67600	17576000	16·1245155	6·3825043	·003846154
261	68121	17779581	16·1554944	6·3906765	·003831418
262	68644	17984728	16·1864141	6·3988279	·003816794
263	69169	18191447	16·2172747	6·4069585	·003802281
264	69696	18399744	16·2480768	6·4150687	·003787879
265	70225	18609625	16·2788206	6·4231583	·003773585
266	70756	18821096	16·3095064	6·4312276	·003759398
267	71289	19034163	16·3401346	6·4392767	·003745318
268	71824	19248832	16·3707055	6·4473057	·003731343
269	72361	19465109	16·4012195	6·4553148	·003717472
270	72900	19683000	16·4316767	6·4633041	·003703704
271	73441	19902511	16·4620776	6·4712736	·003690037
272	73984	20123643	16·4924225	6·4792236	·003676471
273	74529	20346417	16·5227116	6·4871541	·003663004
274	75076	20570824	16·5529454	6·4950653	·003649635
275	75625	20796875	16·5831240	6·5029572	·003636364
276	76176	21024576	16·6132477	6·5108300	·003623188
277	76729	21253933	16·6433170	6·5186839	·003610108
278	77284	21484952	16·6783320	6·5265189	·003597122
279	77841	21717639	16·7032931	6·5343351	·003584229
280	78400	21952000	16·7332005	6·5421326	·003571429
281	78961	22188041	16·7630546	6·5499116	·003558719
282	79524	22425768	16·7928556	6·5576722	·003546099
283	80089	22665187	16·8226038	6·5654144	·003533569
284	80656	22906304	16·8522995	6·5731385	·003522127
285	81225	23149125	16·8819430	6·5808443	·003508772
286	81796	23393656	16·9115345	6·5885323	·003496503
287	82369	23639903	16·9410743	6·5962023	·003484321
288	82944	23887872	16·9705627	6·6038545	·003472222
289	83521	24137569	17·0000000	6·6114890	·003460208
290	84100	24389000	17·0293864	6·6191060	·003448276
291	84681	24642171	17·0587221	6·6267054	·003436426
292	85264	24897088	17·0880075	6·6342874	·003424658
293	85849	25153757	17·1172428	6·6418522	·003412969
294	86436	25412184	17·1464282	6·6493998	·003401361
295	87025	25672375	17·1755640	6·6569302	·003389831
296	87616	25934836	17·2046505	6·6644437	·003378378
297	88209	26198073	17·2336879	6·6719403	·003367003
298	88804	26463592	17·2626765	6·6794200	·003355705

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
299	89401	26730899	17·2916165	6·6868831	·003344482
300	90000	27000000	17·3205081	6·6943295	·003333333
301	90601	27270901	17·3493516	6·7017593	·003322259
302	91204	27543608	17·3781472	6·7091729	·003311258
303	91809	27818127	17·4068952	6·7165700	·003301330
304	92416	28094464	17·4355958	6·7239508	·003289474
305	93025	28372625	17·4642492	6·7313155	·003278689
306	93636	28652616	17·4928557	6·7386641	·003267974
307	94249	28934443	17·5214155	6·7459967	·003257329
308	94864	29218112	17·5499288	6·7533134	·003246753
309	95481	29503629	17·5783958	6·7606143	·003236246
310	96100	29791000	17·6068169	6·7678995	·003225806
311	96721	30080231	17·6351921	6·7751690	·003215434
312	97344	30371328	17·6635217	6·7824229	·003205128
313	97969	30664297	17·6918060	6·7896613	·003194888
314	98596	30959144	17·7200451	6·7968844	·003184713
315	99225	31255875	17·7482393	6·8040921	·003174603
316	99856	31554496	17·7763888	6·8112847	·003164557
317	100489	31855013	17·8044938	6·8184620	·003154574
318	101124	32157432	17·8325545	6·8256242	·003144654
319	101761	32461759	17·8605711	6·8327714	·003134796
320	102400	32768000	17·8885438	6·8399037	·003125000
321	103041	33076161	17·9164729	6·8470213	·003115265
322	103684	33386248	17·9443584	6·8541240	·003105590
323	104329	33698267	17·9722008	6·8612120	·003095975
324	104976	34012224	18·0000000	6·8682855	·003086420
325	105625	34328125	18·0277564	6·8753443	·003076923
326	106276	34645976	18·0554701	6·8823888	·003067485
327	106929	34965783	18·0831413	6·8894188	·003058104
328	107584	35287552	18·1107703	6·8964345	·003048780
329	108241	35611289	18·1383571	6·9034359	·003039514
330	108900	35937000	18·1659021	6·9104232	·003030303
331	109561	36264691	18·1934054	6·9173964	·003021148
332	110224	36594368	18·2208672	6·9243556	·003012048
333	110889	36926037	18·2482876	6·9313008	·003003003
334	111556	37259704	18·2756669	6·9382321	·002994012
335	112225	37595375	18·3030052	6·9451496	·002985075
336	112896	37933056	18·3303028	6·9520533	·002976190
337	113569	38272753	18·3575598	6·9589434	·002967359
338	114244	38614472	18·3847763	6·9658198	·002958580
339	114921	38958219	18·4119526	6·9726826	·002949853
340	115600	39304000	18·4390889	6·9795321	·002941176
341	116281	39651821	18·4661853	6·9863681	·002932551
342	116964	40001688	18·4932420	6·9931906	·002923977
343	117649	40353607	18·5202592	7·0000000	·002915452
344	118336	40707584	18·5472370	7·0067962	·002906977
345	119025	41063625	18·5741756	7·0135791	·002898551
346	119716	41421736	18·6010752	7·0203490	·002890173
347	120409	41781923	18·6279360	7·0271058	·002881844
348	121104	42144192	18·6547581	7·0338497	·002873563
349	121801	42508549	18·6815417	7·0405806	·002865330
350	122500	42875000	18·7082869	7·0472987	·002857143
351	123201	43243551	18·7349940	7·0540041	·002849003
352	123904	43614208	18·7616630	7·0606967	·002840909
353	124609	43986977	18·7882942	7·0673767	·002832861
354	125316	44361864	18·8148877	7·0740440	·002824859
355	126025	44738875	18·8414437	7·0806988	·002816901
356	126736	45118016	18·8679623	7·0873411	·002808989
357	127449	45499293	18·8944436	7·0939709	·002801120
358	128164	45882712	18·9208879	7·1005885	·002793296
359	128881	46268279	18·9472953	7·1071937	·002785515
360	129600	46656000	18·9736660	7·1137866	·002777778

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
361	130321	47045881	19·0000000	7·1203674	·002770083
362	131044	47437928	19·0262976	7·1269360	·002762431
363	131769	47832147	19·0525589	7·1334925	·002754821
364	132496	48228544	19·0787840	7·1400370	·002747253
365	133225	48627125	19·1049732	7·1465695	·002739726
366	133956	49027896	19·1311265	7·1530901	·002732240
367	134689	49430863	19·1572441	7·1595988	·002724796
368	135424	49836032	19·1833261	7·1660957	·002717391
369	136161	50243409	19·2093727	7·1725809	·002710027
370	136900	50653000	19·2353841	7·1790544	·002702703
371	137641	51064811	19·2613603	7·1855162	·002695418
372	138384	51478848	19·2873015	7·1919663	·002688172
373	139129	51895117	19·3132079	7·1984050	·002680965
374	139876	52313624	19·3390796	7·2048322	·002673797
375	140625	52734375	19·3649167	7·2112479	·002666667
376	141376	53157376	19·3907194	7·2176522	·002659574
377	142129	53582633	19·4164878	7·2240450	·002652520
378	142884	54010152	19·4422221	7·2304268	·002645503
379	143641	54439939	19·4679223	7·2367972	·002638521
380	144400	54872000	19·4935887	7·2431565	·002631579
381	145161	55306341	19·5192213	7·2495045	·002624672
382	145924	55742968	19·5448203	7·2558415	·002617801
383	146689	56181887	19·5703858	7·2621675	·002610966
384	147456	56623104	19·5959179	7·2684824	·002604167
385	148225	57066625	19·6214169	7·2747864	·002597403
386	148996	57512456	19·6468827	7·2810794	·002590674
387	149769	57960603	19·6723156	7·2873617	·002583979
388	150544	58411072	19·6977156	7·2936330	·002577320
389	151321	58863869	19·7230829	7·2998936	·002570694
390	152100	59319000	19·7484177	7·3061436	·002564103
391	152881	59776471	19·7737199	7·3123828	·002557545
392	153664	60236288	19·7989899	7·3186114	·002551020
393	154449	60698457	19·8242276	7·3248295	·002544529
394	155236	61162984	19·8494332	7·3310369	·002538071
395	156025	61629875	19·8746069	7·3372339	·002531646
396	156816	62099136	19·8997487	7·3434205	·002525253
397	157609	62570773	19·9248588	7·3495966	·002518892
398	158404	63044792	19·9499373	7·3557624	·002512563
399	159201	63521199	19·9749844	7·3619178	·002506266
400	160000	64000000	20·0000000	7·3680630	·002500000
401	160801	64481201	20·0249844	7·3741979	·002493766
402	161604	64964808	20·0499377	7·3803227	·002487562
403	162409	65450827	20·0748599	7·3864373	·002481390
404	163216	65939264	20·0997512	7·3925418	·002475248
405	164025	66430125	20·1246118	7·3986363	·002469136
406	164836	66923416	20·1494417	7·4047206	·002463054
407	165649	67419143	20·1742410	7·4107950	·002457002
408	166464	67917312	20·1990099	7·4168595	·002450980
409	167281	68417929	20·2237484	7·4229142	·002444988
410	168100	68921000	20·2484567	7·4289589	·002439024
411	168921	69426531	20·2731349	7·4349938	·002433090
412	169744	69934528	20·2977831	7·4410189	·002427184
413	170569	70444997	20·3224014	7·4470342	·002421308
414	171396	70957944	20·3469899	7·4530399	·002415459
415	172225	71473375	20·3715488	7·4590359	·002409639
416	173056	71991296	20·3960781	7·4650223	·002403846
417	173889	72511713	20·4205779	7·4709991	·002398082
418	174724	73034632	20·4450483	7·4769664	·002392344
419	175561	73560059	20·4694895	7·4829242	·002386635
420	176400	74088000	20·4939015	7·4888724	·002380952
421	177241	74618461	20·5182845	7·4948113	·002375297
422	178084	75151448	20·5426386	7·5007406	·002369668

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
423	178929	75686967	20·5669638	7·5066607	·002364066
424	179776	76225024	20·5912603	7·5125715	·002358491
425	180625	76765625	20·6155281	7·5184730	·002352941
426	181476	77308776	20·6397674	7·5243652	·002347418
427	182329	77854483	20·6639783	7·5302482	·002341920
428	183184	78402752	20·6881609	7·5361221	·002336449
429	184041	78953589	20·7123152	7·5419867	·002331002
430	184900	79507000	20·7364414	7·5478423	·002325581
431	185761	80062991	20·7605395	7·5536888	·002320186
432	186624	80621568	20·7846097	7·5595263	·002314815
433	187489	81182737	20·8086520	7·5653548	·002309469
434	188356	81746504	20·8326667	7·5711743	·002304147
435	189225	82312875	20·8566536	7·5769849	·002298851
436	190096	82881856	20·8806130	7·5827865	·002293578
437	190969	83453453	20·9045450	7·5885793	·002288330
438	191844	84027672	20·9284495	7·5943633	·002283105
439	192721	84604519	20·9523268	7·6001385	·002277904
440	193600	85184000	20·9761770	7·6059049	·002272727
441	194481	85766121	21·0000000	7·6116626	·002267574
442	195364	86350888	21·0237960	7·6174116	·002262443
443	196249	86938307	21·0475652	7·6231519	·002257336
444	197136	87528384	21·0713075	7·6288837	·002252252
445	198025	88121125	21·0950231	7·6346067	·002247191
446	198916	88716536	21·1187121	7·6403213	·002242152
447	199809	89314623	21·1423745	7·6460272	·002237136
448	200704	89915392	21·1660105	7·6517247	·002232143
449	201601	90518849	21·1896201	7·6574138	·002227171
450	202500	91125000	21·2132034	7·6630943	·002222222
451	203401	91733851	21·2367606	7·6687665	·002217295
452	204304	92345408	21·2602916	7·6744303	·002212389
453	295209	92959677	21·2837967	7·6800857	·002207506
454	206116	93576664	21·3072758	7·6857328	·002202643
455	207025	94196375	21·3307290	7·6913717	·002197802
456	207936	94818816	21·3541565	7·6970023	·002192982
457	208849	95443993	21·3775583	7·7026246	·092188184
458	209764	96071912	21·4009346	7·7082388	·002183406
459	210681	96702579	21·4242853	7·7188448	·002178649
460	211600	97336000	21·4476106	7·7194426	·002173913
461	212521	97972181	21·4709106	7·7250325	·002169197
462	213444	98611128	21·4941853	7·7306141	·002164502
463	214369	99252847	21·5174348	7·7361877	·002159827
464	215296	99897344	21·5406592	7·7417532	·002155172
465	216225	100544625	21·5638587	7·7473109	·002150538
466	217156	101194696	21·5870331	7·7528606	·002145923
467	218089	101847563	21·6101828	7·7584023	·002141328
468	219024	102503232	21·6333077	7·7639361	·002136752
469	219961	103161709	21·6564078	7·7694620	·002132196
470	220900	103823000	21·6794834	7·7749801	·002127660
471	221841	104487111	21·7025344	7·7804904	·002123142
472	222784	105154048	21·7255610	7·7859928	·002118644
473	223729	105823817	21·7485632	7·7914875	·002114165
474	224676	106496424	21·7715411	7·7969745	·002109705
475	225625	107171875	21·7944947	7·8024538	·002105263
476	226576	107850176	21·8174242	7·8079254	·002100840
477	227529	108531333	21·8403297	7·8133892	·002096486
478	228484	109215352	21·8632111	7·8188456	·002092050
479	229441	109902239	21·8860686	7·8242942	·002087683
480	230400	110592000	21·9089023	7·8297353	·002083333
481	231361	111284641	21·9317122	7·8351688	·002079002
482	232324	111980168	21·9544984	7·8405949	·002074689
483	233289	112678587	21·9772610	7·8460134	·002070393
484	234256	113379904	22·0000000	7·8514244	·002066116

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
485	235225	114084125	22·0227155	7·8568281	·002061856
486	236196	114791256	22·0454077	7·8622242	·002057613
487	237169	115501303	22·0680765	7·8676130	·002053388
488	238144	116214272	22·0907220	7·8729944	·002049180
489	239121	116930169	22·1133444	7·8783684	·002044990
490	240100	117649000	22·1359436	7·8837352	·002040816
491	241081	118370771	22·1585198	7·8890946	·002036660
492	242064	119095488	22·1810730	7·8944468	·002032520
493	243049	119823157	22·2036033	7·8997917	·002028398
494	244036	120553784	22·2261108	7·9051294	·002024291
495	245025	121287375	22·2485955	7·9104599	·002020202
496	246016	122023936	22·2710575	7·9157832	·002016129
497	247009	122763473	22·2934968	7·9210994	·002012072
498	248004	123505992	22·3159136	7·9264085	·002008032
499	249001	124251499	22·3383079	7·9317104	·002004008
500	250000	125000000	22·3606798	7·9370053	·002000000
501	251001	125751501	22·3830293	7·9422931	·001996008
502	252004	126506008	22·4053565	7·9475739	·001992032
503	253009	127263527	22·4276615	7·9528477	·001988072
504	254016	128024064	22·4499443	7·9581144	·001984127
505	255025	128787625	22·4722051	7·9633743	·001980198
506	256036	129554216	22·4944438	7·9686271	·001976285
507	257049	130323843	22·5166605	7·9738731	·001972387
508	258064	131096512	22·5388553	7·9791122	·001968504
509	259081	131872229	22·5610283	7·9843444	·001964637
510	260100	132651000	22·5831796	7·9894697	·001960785
511	261121	133432831	22·6053091	7·9947883	·001956947
512	262144	134217728	22·6274170	8·0000000	·001953125
513	263169	135005697	22·6495033	8·0052049	·001949318
514	264196	135796744	22·6715681	8·0104032	·001945525
515	265225	136590875	22·6936114	8·0155946	·001941748
516	266256	137388096	22·7156334	8·0207794	·001937984
517	267289	138188413	22·7376341	8·0259574	·001934236
518	268324	138991832	22·7596134	8·0311287	·001930502
519	269361	139798359	22·7815715	8·0362935	·001926782
520	270400	140608000	22·8035085	8·0414515	·001923077
521	271411	141420761	22·8254244	8·0466030	·001919386
522	272484	142236648	22·8473193	8·0517479	·001915709
523	273529	143055667	22·8691933	8·0568862	·001912046
524	274576	143877824	22·8910463	8·0620180	·001908397
525	275625	144703125	22·9128785	8·0671432	·001904762
526	276676	145531576	22·9346899	8·0722620	·001901141
527	277729	146363183	22·9564806	8·0773743	·001897533
528	278784	147197952	22·9782506	8·0824800	·001893939
529	279841	148035889	23·0000000	8·0875794	·001890359
530	280900	148877001	23·0217289	8·0926723	·001886792
531	281961	149721291	23·0434372	8·0977589	·001883239
532	283024	150568768	23·0651252	8·1028390	·001879699
533	284089	151419437	23·0867928	8·1079128	·001876173
534	285156	152273304	23·1084400	8·1129803	·001872659
535	286225	153130375	23·1300670	8·1180414	·001869159
536	287296	153990656	23·1516738	8·1230962	·001865672
537	288369	154854153	23·1732605	8·1281447	·001862197
538	289444	155720872	23·1948270	8·1331870	·001858736
539	290521	156590819	23·2163735	8·1382230	·001855288
540	291600	157464000	23·2379001	8·1432529	·001851852
541	292681	158340421	23·2594067	8·1482765	·001848429
542	293764	159220088	23·2808935	8·1532939	·001845018
543	294849	160103007	23·3023604	8·1583051	·001841621
544	295936	160989184	23·3238076	8·1633102	·001838235
545	297025	161878625	23·3452351	8·1683092	·001834862
546	298116	162771336	23·3666429	8·1733020	·001831502

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
547	299209	163667323	23·3880311	8·1782888	·001828154
548	300304	164566592	23·4093998	8·1832695	·001824818
549	301401	165469149	23·4307490	8·1882441	·001821494
550	302500	166375000	23·4520788	8·1932127	·001818182
551	303601	167284151	23·4733892	8·1981753	·001814882
552	304704	168196608	23·4946802	8·2031319	·001811594
553	305809	169112377	23·5159520	8·2080825	·001808318
554	306916	170031464	23·5372046	8·2130271	·001805054
555	308025	170953875	23·5584380	8·2179657	·001801802
556	309136	171879616	23·5796522	8·2228985	·001798561
557	310249	172808693	23·6008474	8·2278254	·001795332
558	311364	173741112	23·6220236	8·2327463	·001792115
559	312481	174676879	23·6431808	8·2376614	·001788909
560	313600	175616000	23·6643191	8·2425706	·001785714
561	314721	176558481	23·6854386	8·2474740	·001782531
562	315844	177504328	23·7065392	8·2523715	·001779359
563	316969	178453547	23·7276210	8·2572633	·001776199
564	318096	179406144	23·7486842	8·2621492	·001773050
565	319225	180362125	23·7697286	8·2670294	·001769912
566	320356	181321496	23·7907545	8·2719039	·001766784
567	321489	182284263	23·8117618	8·2767726	·001763668
568	322624	183250432	23·8327506	8·2816355	·001760563
569	323761	184220009	23·8537209	8·2864928	·001757469
570	324900	185193000	23·8746728	8·2913444	·001754386
571	326041	186169411	23·8956063	8·2961903	·001751313
572	327184	187149248	23·9165215	8·3010304	·001748252
573	328329	188132517	23·9374184	8·3058651	·001745201
574	329476	189119224	23·9582971	8·3106941	·001742164
575	330625	190109375	23·9791576	8·3155175	·001739130
576	331776	191102976	24·0000000	8·3203353	·001736111
577	332929	192100033	24·0208243	8·3251475	·001733102
578	334084	193100552	24·0416306	8·3299542	·001730104
579	335241	194104539	24·0624188	8·3347553	·001727116
580	336400	195112000	24·0831891	8·3395509	·001724138
581	337561	196122941	24·1039416	8·3443410	·001721170
582	338724	197137368	24·1246762	8·3491256	·001718213
583	339889	198155287	24·1453929	8·3539047	·001715266
584	341056	199176704	24·1660919	8·3586784	·001712329
585	342225	200201625	24·1867732	8·3634466	·001709402
586	343396	201230056	24·2074369	8·3682095	·001706485
587	344569	202262003	24·2280829	8·3729668	·001703578
588	345744	203297472	24·2487113	8·3777188	·001700680
589	346921	204336469	24·2693222	8·3824653	·001697793
590	348100	205379000	24·2899156	8·3872065	·001694915
591	349281	206425071	24·3104996	8·3919423	·001692047
592	350464	207474688	24·3310501	8·3966729	·001689189
593	351649	208527857	24·3515913	8·4013981	·001686341
594	352836	209584584	24·3721152	8·4061180	·001683502
595	354025	210644875	24·3926218	8·4108326	·001680672
596	355216	211708736	24·4131112	8·4155419	·001677852
597	356409	212776173	24·4335834	8·4202460	·001675042
598	357604	213847192	24·4540385	8·4249448	·001672241
599	358801	214921799	24·4744765	8·4296383	·001669449
600	360000	216000000	24·4948974	8·4343267	·001666667
601	361201	217081801	24·5153013	8·4390098	·001663894
602	362404	218167208	24·5356883	8·4436877	·001661130
603	363609	219256227	24·5560583	8·4483605	·001658375
604	364816	220348864	24·5764115	8·4530281	·001655629
605	366025	221445125	24·5967478	8·4576906	·001652893
606	367236	222545016	24·6170673	8·4623479	·001650165
607	368449	223648543	24·6373700	8·4670001	·001647446
608	369664	224755712	24·6576560	8·4716471	·001644737

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals
609	370881	225866529	24·6779254	8·4762892	·001642036
610	372100	226981000	24·6981781	8·4809261	·001639344
611	373321	228099131	24·7184142	8·4855579	·001636661
612	374544	229220928	24·7386338	8·4901848	·001633987
613	375769	230346397	24·7588368	8·4948065	·001631321
614	376996	231475544	24·7790234	8·4994233	·001628664
615	378225	232608375	24·7991935	8·5040350	·001626016
616	379456	233744896	24·8193473	8·5086417	·001623377
617	380689	234885113	24·8394847	8·5132435	·001620746
618	381924	236029032	24·8596058	8·5178403	·001618123
619	383161	237176659	24·8797106	8·5224331	·001615509
620	384400	238328000	24·8997992	8·5270189	·001612903
621	385641	239483061	24·9198716	8·5316009	·001610306
622	386884	240641848	24·9399278	8·5361780	·001607717
623	388129	241804367	24·9599679	8·5407501	·001605136
624	389376	242970624	24·9799920	8·5453173	·001602564
625	390625	244140625	25·0000000	8·5498797	·001600000
626	391876	245314376	25·0199920	8·5544372	·001597444
627	393129	246491883	25·0399681	8·5589899	·001594896
628	394384	247673152	25·0599282	8·5635377	·001592357
629	395641	248858189	25·0798724	3·5680807	·001589825
630	396900	250047000	25·0998008	8·5726189	·001587302
631	398161	251239591	25·1197134	8·5771523	·001584786
632	399424	252435968	25·1396102	8·5816809	·001582278
633	400689	253636137	25·1594913	8·5862247	·001579779
634	401956	254840104	25·1793566	8·5907238	·001577287
635	403225	256047875	25·1992063	8·5952380	·001574803
636	404496	257259456	25·2190404	8·5997476	·001572327
637	405769	258474853	25·2388589	8·6042525	·001569859
638	407044	259694072	25·2586619	8·6087526	·001567398
639	408321	260917119	25·2784493	8·6132480	·001564945
640	409600	262144000	25·2982213	8·6177388	·001562500
641	410881	263374721	25·3179778	8·6222248	·001560062
642	412164	264609288	25·3377189	8·6267063	·001557632
643	413449	265847707	25·3574447	8·6311830	·001555210
644	414736	267089984	25·3771551	8·6356551	·001552795
645	416125	268336125	25·3968502	8·6401226	·001550388
646	417316	269585136	25·4165302	8·6445855	·001547988
647	418609	270840023	25·4361947	8·6490437	·001545595
648	419904	272097792	25·4558441	8·6534974	·001543210
649	421201	273359449	25·4754784	8·6579465	·001540832
650	422500	274625000	25·4950976	8·6623911	·001538462
651	423801	275894451	25·5147013	8·6668310	·001536098
652	425104	277167808	25·5342907	8·6712665	·001533742
653	426409	278445077	25·5538647	8·6756974	·001531394
654	427716	279726264	25·5734237	8·6801237	·001529052
655	429025	281011375	25·5929678	8·6845456	·001526718
656	430336	282300416	25·6124969	8·6889630	·001524390
657	431639	283593393	25·6320112	8·6933759	·001522070
658	432964	284890312	25·6515107	8·6977843	·001519751
659	434281	286191179	25·6709953	8·7021882	·001517451
660	435600	287496000	25·6904652	8·7065877	·001515152
661	436921	288804781	25·7099203	8·7109827	·001512859
662	438244	290117528	25·7293607	8·7153734	·001510574
663	439569	291434247	25·7487864	8·7197596	·001508296
664	440896	292754944	25·7681975	8·7241414	·001506024
665	442225	294079625	25·7875939	8·7285187	·001503759
666	443556	295408296	25·8069758	8·7328918	·001501502
667	444899	296740963	25·8263431	8·7372604	·001499250
668	446224	298077632	25·8456960	8·7416246	·001497006
669	447561	299418309	25·8650343	8·7459846	·001494768
670	448900	300763000	25·8843582	8·7503401	·001492537

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
671	450241	302111711	25·9036677	8·7546913	·001490313
672	451584	303464448	25·9229628	8·7590383	·001488095
673	452929	304821217	25·9422435	8·7633809	·001485884
674	454276	306182024	25·9615100	8·7677192	·001483680
675	455625	307546875	25·9807621	8·7720532	·001481481
676	456976	308915776	26·0000000	8·7763830	·001479290
677	458329	310288733	26·0192237	8·7807084	·001477105
678	459684	311665752	26·0384331	8·7850296	·001474926
679	461041	313046839	26·0576284	8·7893466	·001472754
680	462400	314432000	26·0768096	8·7936593	·001470588
681	463761	315821241	26·0959767	8·7979679	·001468429
682	465124	317214568	26·1151297	8·8022721	·001466276
683	466489	318611987	26·1342687	8·8065722	·001464129
684	467856	320013504	26·1533937	8·8108681	·001461988
685	469225	321419125	26·1725047	8·8151598	·001459854
686	470596	322828856	26·1916017	8·8194474	·001457726
687	471969	324242703	26·2106848	8 8237307	·001455604
688	473344	325660672	26·2297541	8·8280099	·001453488
689	474721	327082769	26·2488095	8·8322850	·001451379
690	476100	328509000	26·2678511	8·8365559	·001449275
691	477481	329939371	26·2868789	8·8408227	·001447178
692	478864	331373888	26·3058929	8·8450854	·001445087
693	480249	332812557	26·3248932	8·8493440	·001443001
694	481636	334255384	26·3438797	8·8535985	·001440922
695	483025	335702375	26·3628527	8·8578489	·001438849
696	484416	337153536	26·3818119	8·8620952	·001436782
697	485809	338608873	26·4007576	8·8663375	·001434720
698	487204	340068392	26·4196896	8·8705757	·001432665
699	488601	341532099	26·4386081	8·8748099	·001430615
700	490000	343000000	26·4575131	8·8790400	·001428571
701	491401	344472101	26·4764046	8·8832661	·001426534
702	492804	345948408	26·4952826	8·8874882	·001424501
703	494209	347428927	26·5141472	8·8917063	·001422475
704	495616	348913664	26·5329983	8·8959204	·001420455
705	497025	350402625	26·5518361	8·9001304	·001418440
706	498436	351895816	26·5706605	8·9043366	·001416431
707	499849	353393243	26·5894716	8·9085387	·001414427
708	501264	354894912	26·6082694	8·9127369	·001412429
709	502681	356400829	26·6270539	8·9169311	·001410437
710	504100	357911000	26·6458252	8·9211214	·001408451
711	505521	359425431	26·6645833	8·9253078	·001406470
712	506944	360944128	26·6833281	8·9294902	·001404494
713	508369	362467097	26·7020598	8·9336687	·001402525
714	509796	363994344	26·7207784	8·9378433	·001400560
715	511225	365525875	26·7394839	8·9420140	·001398601
716	512656	367061696	26·7581763	8·9461809	·001396648
717	514089	368601813	26·7768557	8·9503438	·001394700
718	515524	370146232	26·7955220	8·9545029	·001392758
719	516961	371694959	26·8141754	8·9586581	·001390821
720	518400	373248000	26·8328157	8·9628095	·001388889
721	519841	374805361	26·8514432	8·9669570	·001386963
722	521284	376367048	26·8700577	8·9711007	·001385042
723	522729	377933067	26·8886593	8·9752406	·001383126
724	524176	379503424	26·9072481	8·9793766	·001381215
725	525625	381078125	26·9258240	8·9835089	·001379310
726	527076	382657176	26·9443872	8·9876373	·001377410
727	528529	384240583	26·9629375	8·9917620	·001375516
728	529984	385828352	26·9814751	8·9958899	·001373626
729	531441	387420489	27·0000000	9·0000000	·001371742
730	532900	389017000	27·0185122	9·0041134	·001369863
731	534361	390617891	27·0370117	9·0082229	·001367989
732	535824	392223168	27·0554985	9·0123288	·001366120

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
733	537289	393832837	27·0739727	9·0164309	·001364256
734	538756	395446904	27·0924344	9·0205293	·001362398
735	540225	397065375	27·1108834	9·0246239	·001360544
736	541696	398688256	27·1293199	9·0287149	·001358696
737	543169	400315553	27·1477149	9·0328021	·001356852
738	544644	401947272	27·1661554	9·0368857	·001355014
739	546121	403583419	27·1845544	9·0409655	·001353180
740	547600	405224000	27·2029140	9·0450419	·001351351
741	549801	406869021	27·2213152	9·0491142	·001349528
742	550564	408518488	27·2396769	9·0531831	·001347709
743	552049	410172407	27·2580263	9·0572482	·001345895
744	553536	411830784	27·2763634	9·0613098	·001344086
745	555025	413493625	27·2946881	9·0653677	·001342282
746	556516	415160936	27·3130006	9·0694220	·001340483
747	558009	416832723	27·3313007	9·0734726	·001338688
748	559504	418508992	27·3495887	9·0775197	·001336898
749	561001	420189749	27·3678644	9·0815631	·001335113
750	562500	421875000	27·3861279	9·0856030	·001333333
751	564001	423564751	27·4043792	9·0896352	·001331558
752	565504	425259008	27·4226184	9·0936719	·001329787
753	567009	426957777	27·4408455	9·0977010	·001328021
754	568516	428661064	27·4590604	9·1017265	·001326260
755	570025	430368875	27·4772633	9·1057485	·001324503
756	571536	432081216	27·4954542	9·1097669	·001322751
757	573049	433798093	27·5136330	9·1137818	·001321004
758	574564	435519512	27·5317998	9·1177931	·001319261
759	576081	437245479	27·5499546	9·1218010	·001317523
760	577600	438976000	27·5680975	9·1258053	·001315789
761	579121	440711081	27·5862284	9·1298061	·001314060
762	580644	442450728	27·6043475	9·1338034	·001312336
763	582169	444194947	27·6224546	9·1377971	·001310616
764	583696	445943744	27·6405499	9·1417874	·001308901
765	585225	447697125	27·6586334	9·1457742	·001307190
766	586756	449455096	27·6767050	9·1497576	·001305483
767	588289	451217663	27·6947648	9·1537375	·001303781
768	589824	452984832	27·7128129	9·1577139	·001302083
769	591361	454756609	27·7308492	9·1616869	·001300390
770	592900	456533000	27·7488739	9·1656565	·001298701
771	594441	458314011	27·7668868	9·1696225	·001297017
772	595984	460099648	27·7848880	9·1735852	·001295337
773	597529	461889917	27·8028775	9·1775445	·001293661
774	599076	463684824	27·8208555	9·1815003	·001291990
775	600625	465484375	27·8388218	9·1854527	·001290323
776	602176	467288576	27·8567766	9·1894018	·001288660
777	603729	469097433	27·8747197	9·1933474	·001287001
778	605284	470910952	27·8926514	9·1972897	·001285347
779	606841	472729139	27 9105715	9·2012286	·001283697
780	608400	474552000	27·9284801	9·2051641	·001282051
781	609961	476379541	27·9463772	9·2090962	·001280410
782	611524	478211768	27·9642629	9·2130250	·001278772
783	613089	480048687	27·9821372	9·2169505	·001277139
784	614656	481890304	28·0000000	9·2208726	·001275510
785	616225	483736625	28·0178515	9·2247914	·001273885
786	617796	485587656	28·0356915	9·2287068	·001272265
787	619369	487443403	28·0535203	9·2326189	·001270648
788	620944	489303872	28·0713377	9·2365277	·001269036
789	622521	491169069	28·0891438	6·2404333	·001267427
790	624100	493039000	28·1069386	9·2443355	·001265823
791	625681	494913671	28·1247222	9·2482344	·001264223
792	627624	496793088	28·1424946	9·2521300	·001262626
793	628849	498677257	28·1602557	9·2560224	·001261034
794	630436	500566184	28·1780056	9·2599114	·001259446

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
795	632025	502459875	28·1957444	9·2637973	·001257862
796	633616	504358336	28·2134720	9·2676798	·001256281
797	635209	506261573	28·2311884	9·2715592	·001254705
798	636804	508169592	28·2488938	9·2754352	·001253133
799	638401	510082399	28·2665881	8·2793081	·001251364
800	640000	512000000	28·2842712	9·2831777	·001250000
801	641601	513922401	28·3019434	9·2870444	·001248439
802	643204	515849608	28·3196045	9·2909072	·001246883
803	644809	517781627	28·3372546	9·2947671	·001245330
804	646416	519718464	28·3548938	9·2986239	·001243781
805	648025	521660125	28·3725219	9·3024775	·001242236
806	649636	523606616	28·3901391	9·3063278	·001240695
807	651249	525557943	28·4077454	9·3101750	·001239157
808	652864	527514112	28·4253408	9·3140190	·001237624
809	654481	529475129	28·4429253	9·3178599	·001236094
810	656100	531441000	28·4604989	9·3216975	·001234568
811	657721	533411731	28·4780617	9·3255320	·001233046
812	659344	535387328	28·4956137	9·3293634	·001231527
813	660969	537367797	28·5131549	9·3331916	·001230012
814	662596	539353144	28·5306852	9·3370167	·001228501
815	664225	541343375	28·5482048	9·3408386	·001226994
816	665856	543338496	28·5657137	9·3446575	·001225490
817	667489	545338513	28·5832119	9·3484731	·001223990
818	669124	547343432	28·6006993	9·3522857	·001222494
819	670761	549353259	28·6181760	9·3560952	·001221001
820	672400	551368000	28·6356421	9·3599016	·001219512
821	674041	553387661	28·6530976	9·3637049	·001218027
822	675684	555412248	28·6705424	9·3675051	·001216545
823	677329	557441767	28·6879766	9·3713022	·001215067
824	678976	559476224	28·7054002	9·3750963	·001213592
825	680625	561515625	28·7228132	9·3788873	·001212121
826	682276	563559976	28·7402157	9·3826752	·001210654
827	683929	565609283	28·7576077	9·3864600	·001209190
828	685584	567663552	28·7749891	9·3902419	·001207729
829	687241	569722789	28·7923601	9·3940206	·001206273
830	688900	571787000	28·8097206	9·3977964	·001204819
831	690561	573856191	28·8270706	9·4015691	·001203369
832	692224	575930368	28·8444102	9·4053387	·001201923
833	693889	578009537	28·8617394	9·4091054	·001200480
834	695556	580093704	28·8790582	9·4128690	·001199041
835	697225	582182875	28·8963666	9·4166297	·001197605
836	698896	584277056	28·9136646	9·4203873	·001196172
837	700569	586376253	28·9309523	9·4241420	·001194743
838	702244	588480472	28·9482297	9·4278936	·001193317
839	703921	590589719	28·9654967	9·4316423	·001191895
840	705600	592704000	28·9827535	9·4353880	·001190476
841	707281	594823321	29·0000000	9·4391307	·001189061
842	708964	596947688	29·0172363	9·4428704	·001187648
843	710649	599077107	29·0344623	9·4466072	·001186240
844	712336	601211584	29·0516781	9·4503410	·001184834
845	714025	603351125	29·0688837	9·4540719	·001183432
846	715716	605495736	29·0860791	9·4577999	·001182033
847	717409	607645423	29·1032644	9·4615249	·001180638
848	719104	609800192	29·1204396	9·4652470	·001179245
849	720801	611960049	29·1376046	9·4689661	·001177856
850	722500	614125000	29·1547595	9·4726824	·001176471
851	724201	616295051	29·1719043	9·4763957	·001175088
852	725904	618470208	29·1890390	9·4801061	·001173709
853	727609	620650477	29·2061637	9·4838136	·001272333
854	729316	622835864	29·2232784	9·4875182	·001170960
855	731025	625026375	29·2403830	9·4912200	·001169591
856	732736	627222016	29·2574777	9·4949188	·001168224

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
857	734449	629422793	29·2745623	9·4986147	·001166861
858	736164	631628712	29·2916370	9·5023078	·001165501
859	737881	633839779	29·3087018	9·5059980	·001164144
860	739600	636056000	29·3257566	9·5096854	·001162791
861	741321	638277381	29·3428015	9·5133699	·001161440
862	743044	640503928	29·3598365	9·5170515	·001160093
863	744769	642735647	29·3768616	9·5207303	·001158749
864	746496	644972544	29·3938769	9·5244063	·001157407
865	748225	647214625	29·4108823	9·5280794	·001156069
866	749956	649461896	29·4278779	9·5317497	·001154734
867	751689	651714363	29·4448637	9·5354172	·001153403
868	753424	653972032	29·4618397	9·5390818	·001152074
869	755161	656234909	29·4788059	9·5427437	·001150748
870	756900	658503000	29·4957624	9·5464027	·001149425
871	758641	660776311	29·5127091	9·5500589	·001148106
872	760384	663054848	29·5296461	9·5537123	·001146789
873	762129	665338617	29·5465734	9·5573630	·001145475
874	763876	667627624	29·5634910	9·5610108	·001144165
875	765625	669921875	29·5803989	9·5646559	·001142857
876	767376	672221376	29·5972972	9·5682782	·001141553
877	769129	674526133	29·6141858	9·5719377	·001140251
878	770884	676836152	29·6310648	9·5755745	·001138952
879	772641	679151439	29·6479342	9·5792085	·001137656
880	774400	681472000	29·6647939	9·5828397	·001136364
881	776161	683797841	29·6816442	9·5864682	·001135074
882	777924	686128968	29·6984848	9·5900937	·001133787
883	779689	688465387	39·7153159	9·5937169	·001132503
884	781456	690807104	29·7321375	9·5973373	·001131222
885	783225	693154125	29·7489496	9·6009548	·001129944
886	784996	695506456	29·7657521	9·6045696	·001128668
887	786769	697864103	29·7825452	9·6081817	·001127396
888	788544	700227072	29·7993289	9·6117911	·001126126
889	790321	702595369	29·8161030	9·6153977	·001124859
890	792100	704969000	29·8328678	9·6190017	·001123596
891	793881	707347971	29·8496231	9·6226030	·001122334
892	795664	707932288	29·8663690	9·6262016	·001121076
893	797449	712121957	29·8831056	9·6297975	·001119821
894	799236	714516984	29·8998328	9·6333907	·001118568
895	801025	716917375	29·9165506	9·6369812	·001117818
896	802816	719323136	29·9332591	9·6405690	·001116071
897	804609	721734273	29·9499583	9·6441542	·001114827
898	806404	724150792	29·9666481	9·6477367	·001113586
899	808201	726572699	29·9833287	9·6513166	·001112347
900	810000	729000000	30·0000000	9·6548938	·001111111
901	811801	731432701	30·0166621	9·6584684	·001189878
902	813604	733870808	30·0333148	9·6620403	·001108647
903	815409	736314327	30·0499584	9·6656096	·001107420
904	817216	738763264	30·0665928	9·6691762	·001106195
905	819025	741217625	30·0832179	9·6727403	·001104972
906	820836	743677416	30·0998339	9·6763017	·001103753
907	822649	746142643	30·1164407	9·6798604	·001102536
908	824464	748613312	30·1330383	9·6834166	·001101322
909	826281	751089429	30·1496269	9·6869701	·001100110
910	828100	753571000	30·1662063	9·6905211	·001098901
911	829921	756058031	30·1827765	9·6940694	·001091695
912	831744	758550825	30·1993377	9·6976151	·001096491
913	833569	761048497	30·2158899	9·7011583	·001095290
914	835396	763551944	30·2324329	9·7046989	·001094092
915	837225	766060875	30·2489669	9·7082369	·001092896
916	839056	768575296	30·2654919	9·7117723	·001091703
917	840889	771095213	30·2820079	9·7153051	·001090513
918	842724	773620632	30·2985148	9·7188354	·001089325

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
919	844561	776151559	30·3150128	9·7223631	·001088139
920	846400	778688000	30·3315018	9·7258883	·001086957
921	848241	781229961	30·3479818	9·7294109	·001085776
922	850084	783777448	30·3644529	9·7329309	·001084599
923	851929	786330467	30·3809151	9·7364484	·001083423
924	853776	788889024	30·3973683	9·7399634	·001082251
925	855625	791453125	30·4138127	9·7434758	·001081081
926	857476	794022776	30·4302481	9·7469857	·001079914
927	859329	796597983	30·4466747	9·7504930	·001078749
928	861184	799178752	30·4630924	9·7539979	·001077586
929	863041	801765089	30·4795013	9·7575002	·001076426
930	864900	804357000	30·4959014	9·7610001	·001075269
931	866761	806954491	30·5122926	9·7644974	·001074114
932	868624	809557568	30·5286750	9·7679922	·001072961
933	870489	812166237	30·5450487	9·7714845	·001071811
934	872356	814780504	30·5614136	9·7749743	·001070664
935	874225	817400375	30·5777697	9·7784616	·001069519
936	876096	820025856	30·5941171	9·7829466	·001068376
937	877969	822656953	30·6104557	9·7854288	·001067236
938	879844	825293672	30·6267857	9·7889087	·001066098
939	881721	827936019	30·6431069	9·7923861	·001064963
940	883600	830584000	30·6594194	9·7958611	·001063830
941	885481	833237621	30·6757233	9·7993336	·001062699
942	887364	835896888	30·6920185	9·8028036	·001061571
943	889249	838561807	30·7083051	9·8062711	·001060445
944	891136	841232384	30·7245830	9·8097362	·001059322
945	893025	843908625	30·7408523	9·8131989	·001058201
946	894916	846590536	30·7571130	9·8166591	·001057082
947	896808	849278123	30·7733651	9·8201169	·001055966
948	898704	851971392	30·7896086	9·8235723	·001054852
949	900601	854670349	30·8058436	9·8270252	·001053741
950	902500	857375000	30·8220700	9·8304757	·001052632
951	904401	860085351	30·8382879	9·8339238	·001051525
952	906304	862801408	30·8544972	9·8373695	·001050420
953	908209	865523177	30·8706981	9·8408127	·001049318
954	910116	868250664	30·8868904	9·8442536	·001048218
955	912025	870983875	30·9030743	9·8476920	·001047120
956	913936	873722816	30·9192477	9·8511280	·001046025
957	915849	876467493	30·9354166	9·8545617	·001044932
958	917764	879217912	30.9515751	9·8579929	·001043841
959	919681	881974079	30·9677251	9·8614218	·001042753
960	921600	884736000	30·9838668	9·8648483	·001041667
961	923521	887503681	31·0000000	9·8682724	·001040583
962	925444	890277128	31·0161248	9·8716941	·001039501
963	927369	893056347	31·0322413	9·8751135	·001038422
964	929296	895841344	31·0483494	9·8785305	·001037344
965	931225	898632125	31·0644491	9·8819451	·001036269
966	933156	901428696	31·0805405	9·8853574	·001035197
967	935089	904231063	31·0966236	9·8887673	·001034126
968	937024	907039232	31·1126984	9·8921749	·001033058
969	938961	909853209	31·1287648	9·8955801	·001031992
970	940900	912673000	31·1448230	9·8989830	·001030928
971	942841	915498611	31·1608729	9·9023835	·001029866
972	944784	918330048	31·1769145	9·9057817	·001028807
973	946729	921167317	31·1929479	9·9091776	·001027749
974	948676	924010424	31·2089731	9·9125712	·001026694
975	950625	926859375	31·2249900	9·9159624	·001025641
976	952576	929714176	31·2409987	9·9193513	·001024590
977	954529	932574833	31·2569992	9·9227379	·001023541
978	956484	935441352	31·2729915	9·9261222	·001022495
979	958441	938313739	31·2889757	9·9295042	·001021450
980	960400	941192000	31·3049517	9·9328839	·001020408

No.	Squares.	Cubes.	Square Roots.	Cube Roots.	Reciprocals.
981	962361	944076141	31·3209195	9·9362613	·001019168
982	964324	946966168	31·3368792	9·9396363	·001018330
983	966289	949862087	31·3528308	9·9430092	·001017294
984	968256	952763904	31·3687743	9·9463797	·001016260
985	970225	955671625	31·3847097	9·9497479	·001015228
986	972196	958585256	31·4006369	9·9531138	·001014199
987	974169	961504803	31·4165561	9·9564775	·001013171
988	976144	964430272	31·4324673	9·9598389	·001012146
989	978121	967361669	31·4483704	9·9631981	·001011122
990	980100	970299000	31·4642654	9·9665549	·001010101
991	982081	973242271	31·4801525	9·9699095	·001009082
992	984064	976191488	31·4960315	9·9732619	·001008065
993	986049	979146657	31·5119025	9·9766120	·001007049
994	988036	982107784	31·5277655	9·9799599	·001006036
995	990025	985074875	31·5436206	9·9833055	·001005025
996	992016	988047936	31·5594677	9·9866488	·001004016
997	994009	991026973	31·5753068	9·9899900	·001003009
998	996004	994011992	31·5911380	9·9933289	·001002004
991	998001	997002999	31·6069613	9·9966656	·001001001
1000	1000000	1000000000	31·6227766	10·0000000	·001000000
1001	1002001	1003003001	31·6385840	10·0033222	·0009990010
1002	1004004	1006012008	31·6543836	10·0066622	·0009980040
1003	1006009	1009027027	31·6701752	10·0099899	·0009970090
1004	1008016	1012048064	31·6859590	10·0133155	·0009960159
1005	1010025	1015075125	31·7017349	10·0166389	·0009950249
1006	1012036	1018108216	31·7175030	10·0199601	·0009940358
1007	1014049	1021147343	31·7332633	10·0232791	·0009930487
1008	1016064	1024192512	31·7490157	10·0265958	·0009920635
1009	1018081	1027243729	31·7647603	10·0299104	·0009910803
1010	1020100	1030301000	31·7804972	10·0332228	·0009900990
1011	1022121	1033364331	31·7962262	10·0365330	·0009891197
1012	1024144	1036433728	31·8119474	10·0398410	·0009881423
1013	1026169	1039509197	31·8276609	10·0431469	·0009871668
1014	1028196	1042590744	31·8433666	10·0464506	·0009861933
1015	1030225	1045678375	31·8590646	10·0497521	·0009852217
1016	1032256	1048772096	31·8747549	10·0530514	·0009842520
1017	1034289	1051871913	31·8904374	10·0563485	·0009832842
1018	1036324	1054977832	31·9061123	10·0596435	·0009823183
1019	1038361	1058089859	31·9217794	10·0629364	·0009813543
1020	1040400	1061208000	31·9374388	10·0662271	·0009803922
1021	1042441	1064332261	31·9530906	10·0695156	·0009794319
1022	1044484	1067462648	31·9687347	10·0728020	·0009784736
1023	1046529	1070599167	31·9843712	10·0760863	·0009775171
1024	1048576	1073741824	32·0000000	10·0793684	·0009765625
1025	1050625	1076890625	32·0156212	10·0826484	·0009756098
1026	1052676	1080045576	32·0312348	10·0859262	·0009746589
1027	1054729	1083206683	32·0468407	10·0892019	·0009737098
1028	1056784	1086373952	32·0624391	10·0924755	·0009727626
1029	1058841	1089547389	32·0780298	10·0957469	·0009718173
1030	1060900	1092727000	32·0936131	10·0990163	·0009708738
1031	1062961	1095912791	32·1091887	10·1022835	·0009699321
1032	1065024	1099104768	32·1247568	10·1055487	·0009689922
1033	1067089	1102302937	32·1403173	10·1088117	·0009680542
1034	1069156	1105507304	32·1558704	10·1120726	·0009671180
1035	1071225	1108717875	32·1714159	10·1153314	·0009661836
1036	1073296	1111934656	32·1869539	10·1185882	·0009652510
1037	1075369	1115157653	32·2024844	10·1218428	·0009643202
1038	1077444	1118386872	32·2180074	10·1250953	·0009633911
1039	1079521	1121622319	32·2335229	10·1283457	·0009624639
1040	1081600	1124864000	32·2490310	10·1315941	·0009615385
1041	1083681	1128111921	32·2645316	10·1348403	·0009606148
1042	1085764	1131366088	32·2800248	10·1380845	·0009596929

CIRCUMFERENCES AND AREAS OF CIRCLES.

SHOWING ALSO

SIDE OF SQUARE OF EQUAL AREA.

Diameter.	Circumference.	Area.	Area.	Diameter.	Circumference.	Area.	Area.
inches.	feet. in.	square in.	square feet.	inches.	feet. in.	square in.	square feet.
				4	1 0½	12·566	·0879
·0625	·196	·0030	·0554	4⅛	1 0⅞	13·364	·0935
·125	·392	·0122	·1107	4¼	1 1⅜	14·186	·0993
·1875	·589	·0276	·1661	4⅜	1 1¾	15·033	·1052
·25	·785	·0490	·2115	4½	1 2⅛	15·904	·1113
·3125	·981	·0767	·2669	4⅝	1 2½	16·800	·1176
·3750	1·178	·1104	·3223	4¾	1 2⅞	17·720	·1240
·4375	1·374	·1503	·3771	4⅞	1 3¼	18·665	·1306
·50	1·570	·1963	·4331	5	1 3⅝	19·635	·1374
·5625	1·767	·2485	·4995	5⅛	1 4⅛	20·629	·1444
·625	1·963	·3068	·5438	5¼	1 4½	21·647	·1515
·6875	2·159	·3712	·6093	5⅜	1 4⅞	22·690	·1588
·75	2·356	·4417	·6646	5½	1 5¼	23·758	·1663
·8125	2·552	·5185	·7200	5⅝	1 5⅝	24·850	·1739
·8750	2·748	·6013	·7754	5¾	1 6	25·967	·1817
·9375	2·945	·6903	·8308	5⅞	1 6⅜	27·108	·1897
1	3⅛	·7854	·8862	6	1 6¾	28·274	·1979
1⅛	3½	·9940	·9969	6⅛	1 7¼	29·464	·2062
1¼	3⅞	1·227	1·0775	6¼	1 7⅝	30·679	·2147
1⅜	4¼	1·484	1·2185	6⅜	1 8	31·919	·2234
1½	4⅝	1·767	1·3293	6½	1 8⅜	33·183	·2322
1⅝	5⅛	2·074	1·4401	6⅝	1 8¾	34·471	·2412
1¾	5½	2·405	1·5508	6¾	1 9⅛	35·784	·2504
1⅞	5⅞	2·761	1·6616	6⅞	1 9½	37·122	·2598
2	6¼	3·141	1·7724	7	1 10	38·484	·2693
2⅛	6⅝	3·546	1·8831	7⅛	1 10⅜	39·871	·2791
2¼	7	3·976	1·9939	7¼	1 10¾	41·282	·2889
2⅜	7⅜	4·430	2·1047	7⅜	1 11⅛	42·718	·2990
2½	7¾	4·908	2·2155	7½	1 11½	44·178	·3092
2⅝	8¼	5·412	2·3262	7⅝	1 11⅞	45·663	·3196
2¾	8⅝	5·939	2·4370	7¾	2 0⅜	47·173	·3299
2⅞	9	6·491	2·5478	7⅞	2 0¾	48·707	·3409
3	9⅜	7·068	2·6586	8	2 1⅛	50·265	·3518
3⅛	9¾	7·669	2·7694	8⅛	2 1½	51·848	·3629
3¼	10¼	8·295	2·8801	8¼	2 1⅞	53·456	·3741
3⅜	10⅝	8·946	2·9909	8⅜	2 2¼	55·088	·3856
3½	11	9·621	3·1017	8½	2 2⅝	56·745	·3972
3⅝	11⅜	10·320	3·2124	8⅝	2 3	58·426	·4089
3¾	11¾	11·044	3·3232	8¾	2 3⅜	60·132	·4209
3⅞	12⅛	11·793	3·4340	8⅞	2 3⅞	61·862	·4330

Diameter.	Circumference.		Area.	Area.	Diameter.	Circumference.		Area.	Area.
inches.	feet.	in.	square in.	square feet.	inches.	feet.	in.	square in.	square feet.
9	2	4¼	63·617	·4453	16	4	2¼	201·062	1·4074
9⅛	2	4⅝	65·396	·4577	16⅛	4	2⅝	204·216	1·4295
9¼	2	5	67·200	·4704	16¼	4	3	207·394	1·4517
9⅜	2	5⅜	69·029	·4832	16⅜	4	3⅜	210·597	1·4741
9½	2	5¾	70·882	·4961	16½	4	3¾	213·825	1·4967
9⅝	2	6¼	72·759	·5093	16⅝	4	4¼	217·077	1·5195
9¾	2	6⅝	74·662	·5226	16¾	4	4⅝	220·353	1·5424
9⅞	2	7	76·588	·5361	16⅞	4	5	223·654	1·5655
10	2	7⅜	78·540	·5497	17	4	5⅜	226·980	1·5888
10⅛	2	7¾	80·515	·5636	17⅛	4	5¾	230·330	1·6123
10¼	2	8⅛	82·516	·5776	17¼	4	6⅛	233·705	1·6359
10⅜	2	8½	84·540	·5917	17⅜	4	6½	237·104	1·6597
10½	2	8⅞	86·590	·6061	17½	4	6⅞	240·528	1·6836
10⅝	2	9⅜	88·664	·6206	17⅝	4	7⅜	243·977	1·7078
10¾	2	9¾	90·762	·6353	17¾	4	7¾	247·450	1·7321
10⅞	2	10⅛	92·855	·6499	17⅞	4	8⅛	250·947	1·7566
11	2	10½	95·033	·6652	18	4	8½	254·469	1·7812
11⅛	2	10⅞	97·205	·6804	18⅛	4	8⅞	258·016	1·8061
11¼	2	11¼	99·402	·6958	18¼	4	9¼	261·587	1·8311
11⅜	2	11¾	101·623	·7143	18⅜	4	9¾	265·182	1·8562
11½	3	0⅛	103·869	·7270	18½	4	10⅛	268·803	1·8816
11⅝	3	0½	106·139	·7429	18⅝	4	10½	272·447	1·9071
11¾	3	0⅞	108·434	·7590	18¾	4	10⅞	276·117	1·9328
11⅞	3	1¼	110·753	·7752	18⅞	4	11¼	279·811	1·9586
12	3	1⅝	113·097	·7916	19	4	11⅝	283·529	1·9847
12⅛	3	2	115·466	·8082	19⅛	5	0	287·272	1·9941
12¼	3	2½	117·859	·8250	19¼	5	0½	291·039	2·0371
12⅜	3	2⅞	120·276	·8419	19⅜	5	0⅞	294·831	2·0637
12½	3	3¼	122·718	·8590	19½	5	1¼	298·648	2·0904
12⅝	3	3⅝	125·185	·8762	19⅝	5	1⅝	302·489	2·1172
12¾	3	4	127·676	·8937	19¾	5	2	306·355	2·1443
12⅞	3	4⅜	130·192	·9113	19⅞	5	2⅜	310·245	2·1716
13	3	4¾	132·732	·9291	20	5	2⅞	314·160	2·1990
13⅛	3	5¼	135·297	·9470	20⅛	5	3¼	318·099	2·2265
13¼	3	5⅝	137·886	·9642	20¼	5	3⅝	322·063	2·2543
13⅜	3	6	140·500	·9835	20⅜	5	4	326·051	2·2822
13½	3	6⅜	143·139	1·0019	20½	5	4⅜	330·064	2·3103
13⅝	3	6¾	145·802	1·0206	20⅝	5	4¾	334·101	2·3386
13¾	3	7⅛	148·489	1·0294	20¾	5	5⅛	338·163	2·3670
13⅞	3	7½	151·201	1·0584	20⅞	5	5½	342·250	2·3956
14	3	7⅞	153·938	1·0775	21	5	5⅞	346·361	2·4244
14⅛	3	8⅜	156·699	1·0968	21⅛	5	6⅜	350·497	2·4533
14¼	3	8¾	159·485	1·1193	21¼	5	6¾	354·657	2·4824
14⅜	3	9⅛	162·295	1·1360	21⅜	5	7⅛	358·841	2·5117
14½	3	9½	165·130	1·1569	21½	5	7½	363·051	2·5412
14⅝	3	9⅞	167·989	1·1749	21⅝	5	7⅞	367·284	2·5708
14¾	3	10¼	170·873	1·1961	21¾	5	8¼	371·543	2·6007
14⅞	3	10¾	173·782	1·2164	21⅞	5	8¾	375·826	2·6306
15	3	11⅛	176·715	1·2370	22	5	9⅛	380·133	2·6608
15⅛	3	11½	179·672	1·2577	22⅛	5	9½	384·465	2·6691
15¼	3	11⅞	182·654	1·2785	22¼	5	9⅞	388·822	2·7016
15⅜	4	0¼	185·661	1·2996	22⅜	5	10¼	393·208	2·7224
15½	4	0⅝	188·692	1·3208	22½	5	10⅝	397·608	2·7632
15⅝	4	1	191·748	1·3422	22⅝	5	11	402·038	2·7980
15¾	4	1½	194·828	1·3637	22¾	5	11½	406·493	2·8054
15⅞	4	1⅞	197·933	1·3855	22⅞	5	11⅞	410·972	2·8658

Diameter.	Circumference.	Area.	Area.	Diameter.	Circumference.	Area.	Area.
feet. in.	feet. in.	square in.	square feet.	feet. in.	feet. in.	square in.	square feet.
1 11	6 0¼	415·476	2·8903	3 0	9 5	1017·87	7·0688
1 11⅛	6 0⅝	420·004	2·9100	3 0¼	9 5⅞	1032·06	7·1671
1 11¼	6 1	424·557	2·9518	3 0½	9 6⅝	1046·35	7·2664
1 11⅜	6 1⅜	429·135	2·9937	3 0¾	9 7½	1060·73	7·3662
1 11½	6 1¾	433·737	3·0129	3 1	9 8¼	1075·21	7·4661
1 11⅝	6 2¼	438·363	3·0261	3 1¼	9 9	1089·79	7·5671
1 11¾	6 2⅝	443·014	3·0722	3 1½	9 9⅞	1104·46	7·6691
1 11⅞	6 3	447·690	3·1081	3 1¾	9 10½	1119·24	7·7791
2 0	6 3⅜	452·390	3·1418	3 2	9 11⅜	1134·12	7·8681
2 0¼	6 4½	461·864	3·2075	3 2¼	10 0⅛	1149·09	7·9791
2 0½	6 4⅞	471·436	3·2731	3 2½	10 0⅞	1164·16	8·0846
2 0¾	6 5¾	481·106	3·3410	3 2¾	10 1¾	1179·32	8·1891
2 1	6 6½	490·875	3·4081	3 3	10 2½	1194·59	8·2951
2 1¼	6 7¼	500·741	3·4775	3 3¼	10 3¼	1209·95	8·4026
2 1½	6 8⅛	510·706	3.5468	3 3½	10 4	1225·42	8·5091
2 1¾	6 8⅞	520·769	3·6101	3 3¾	10 4⅞	1240·98	8·6171
2 2	6 9⅝	530·930	3·6870	3 4	10 5⅝	1256·64	8·7269
2 2¼	6 10½	541·189	3·7583	3 4¼	10 6⅜	1272·39	8·8361
2 2½	6 11¼	551·547	3·8302	3 4½	10 7¼	1288·25	8·9462
2 2¾	7 0	562·002	3·9042	3 4¾	10 8	1304·20	9·0561
2 3	7 0¾	572·556	3·9761	3 5	10 8¾	1320·25	9·1686
2 3¼	7 1⅝	583·208	4·0500	3 5¼	10 9½	1336·40	9·2112
2 3½	7 2⅜	593·958	4·1241	3 5½	10 10⅜	1352·65	9·3936
2 3¾	7 3⅛	604·807	4·2000	3 5¾	10 11⅛	1369·00	9·5061
2 4	7 3⅞	615·753	4·2760	3 6	10 11⅞	1385·44	9·6212
2 4¼	7 4¾	626·798	4·3521	3 6¼	11 0¾	1401·98	9·7364
2 4½	7 5½	637·941	4·4302	3 6½	11 1½	1418·62	9·8518
2 4¾	7 6¼	649·182	4·5083	3 6¾	11 2¼	1435·36	9·9671
2 5	7 7	660·521	4·5861	3 7	11 3	1452·20	10·084
2 5¼	7 7⅞	671·958	4·6665	3 7¼	11 3⅞	1469·14	10·202
2 5½	7 8⅝	683·494	4·7467	3 7½	11 4⅝	1486·17	10·320
2 5¾	7 9½	695·128	4·8274	3 7¾	11 5⅜	1503·30	10·439
2 6	7 10¼	706·860	4·9081	3 8	11 6¼	1520·53	10·559
2 6¼	7 11	718·690	4·9901	3 8¼	11 7	1537·86	10·679
2 6½	7 11¾	730·618	5·0731	3 8½	11 7¾	1555·28	10·800
2 6¾	8 0⅝	742·644	5·1573	3 8¾	11 8½	1572·81	10·922
2 7	8 1⅜	754·769	5·2278	3 9	11 9⅜	1590·43	11·044
2 7¼	8 2⅛	766·992	5·3264	3 9¼	11 10⅛	1608·15	11·167
2 7½	8 2⅞	779·313	5·4112	3 9½	11 10⅞	1625·97	11·291
2 7¾	8 3¾	791·732	5·4982	3 9¾	11 11¾	1643·89	11·415
2 8	8 4½	804·249	5·5850	3 10	12 0½	1661·90	11·534
2 8¼	8 5⅜	816·865	5·6729	3 10¼	12 1¼	1680·02	11·666
2 8½	8 6⅛	829·578	5·7601	3 10½	12 2	1698·23	11·793
2 8¾	8 6⅞	842·390	5·8491	3 10¾	12 2⅞	1716·54	11·920
2 9	8 7⅝	855·300	5·9398	3 11	12 3⅝	1734·94	12·048
2 9¼	8 8½	868·308	6·0291	3 11¼	12 4⅜	1753·45	12·176
2 9½	8 9¼	881·415	6·1201	3 11½	12 5¼	1772·05	12·305
2 9¾	8 10	894·619	6·2129	3 11¾	12 6	1790·76	12·435
2 10	8 10¾	907·922	6·3051	4 0	12 6¾	1809·56	12·566
2 10¼	8 11½	921·323	6·3981	4 0¼	12 7½	1828·46	12·697
2 10½	9 0⅜	934·822	6·4911	4 0½	12 8⅜	1847·45	12·829
2 10¾	9 1⅛	948·419	6·5863	4 0¾	12 9⅛	1866·55	12·962
2 11	9 1⅞	962·115	6·6815	4 1	12 9⅞	1885·74	13·095
2 11¼	9 2¾	975·908	6·7772	4 1¼	12 10¾	1905·03	13·229
2 11½	9 3½	989·800	6·8738	4 1½	12 11½	1924·42	13·364
2 11¾	9 4¼	1003·79	6·9701	4 1¾	13 0¼	1943·91	13·499

Diameter.	Circumference.	Area.	Area.	Diameter.	Circumference.	Area.	Area.
feet. in.	feet. in.	square in.	square feet.	feet. in.	feet. in.	square in.	square feet.
4 2	13 1	1963·50	13·635	5 4	16 9	3216·99	22·333
4 2¼	13 1⅞	1983·18	13·772	5 4¼	16 9¾	3242·17	22·515
4 2½	13 2⅝	2002·96	13·909	5 4½	16 10⅝	3267·46	22·621
4 2¾	13 3⅜	2022·84	14·047	5 4¾	16 11⅜	3292·83	22·866
4 3	13 4¼	2042·82	14·186	5 5	17 0⅛	3318·31	23·043
4 3¼	13 5	2062·90	14·325	5 5¼	17 0⅞	3343·88	23·221
4 3½	13 5¾	2083·07	14·465	5 5½	17 1¾	3369·56	23·330
4 3¾	13 6½	2103·35	14·606	5 5¾	17 2½	3395·33	23·578
4 4	13 7⅜	2123·72	14·748	5 6	17 3⅜	3421·20	23·758
4 4¼	13 8⅛	2144·19	14·890	5 6¼	17 4⅛	3447 16	23·938
4 4½	13 8⅞	2164·75	15·033	5 6½	17 4⅞	3473·23	24·119
4 4¾	13 9¾	2185·42	15·176	5 6¾	17 5⅝	3499·39	24·301
4 5	13 10½	2206·18	15·320	5 7	17 6½	3525·66	24 483
4 5¼	13 11¼	2227·05	15·465	5 7¼	17 7¼	3552·01	24·666
4 5½	14 0	2248·01	15·611	5 7½	17 8	3578·47	24·850
4 5¾	14 0⅞	2269·06	15·757	5 7¾	17 8¾	3605·03	25·034
4 6	14 1⅝	2290·22	15·904	5 8	17 9⅝	3631·68	25·220
4 6¼	14 2⅜	2311·48	16·051	5 8¼	17 10⅜	3658·44	25·405
4 6½	14 3¼	2332·83	16·200	5 8½	17 11⅛	3685·29	25·592
4 6¾	14 4	2354·28	16·349	5 8¾	17 11⅞	3712·24	25·779
4 7	14 4¾	2375·83	16·498	5 9	18 0¾	3739·28	25·964
4 7¼	14 5½	2397·48	16·649	5 9¼	18 1½	3766·43	26·155
4 7½	14 6⅜	2419·22	16·800	5 9½	18 2¼	3793·67	26·344
4 7¾	14 7⅛	2441·07	16·951	5 9¾	18 3⅛	3821·02	26·534
4 8	14 7⅞	2463·01	17·104	5 10	18 3⅞	3848·46	26·725
4 8¼	14 8⅝	2485·05	17·257	5 10¼	18 4⅝	3875·99	26·916
4 8½	14 9½	2507·19	17·411	5 10½	18 5½	3903·63	27·108
4 8¾	14 10¼	2529·42	17·565	5 10¾	18 6¼	3931·36	27·301
4 9	14 11	2551·76	17·720	5 11	18 7	3959·20	27·494
4 9¼	14 11⅞	2574·19	17·876	5 11¼	18 7¾	3987·13	27·688
4 9½	15 0⅝	2596·72	18·033	5 11½	18 8⅝	4015·16	27·883
4 9¾	15 1⅜	2619·35	18·189	5 11¾	18 9⅜	4043·28	28·078
4 10	15 2¼	2642·08	18·347	6 0	18 10⅛	4071·51	28·274
4 10¼	15 2⅞	2664·91	18·506	6 0¼	18 10⅞	4099·83	28·471
4 10½	15 3¾	2687·83	18·665	6 0½	18 11¾	4128·25	28·668
4 10¾	15 4½	2710·85	18·825	6 0¾	19 0½	4156·77	28·866
4 11	15 5¼	2733·97	18·985	6 1	19 1¼	4185·39	29·065
4 11¼	15 6⅛	2757·19	19·147	6 1¼	19 2⅛	4214·11	29·264
4 11½	15 6⅞	2780·51	19·309	6 1½	19 2⅞	4242·92	29·466
4 11¾	15 7¾	2803·92	19·471	6 1¾	19 3⅝	4271·83	29·665
5 0	15 8½	2827·44	19·635	6 2	19 4½	4300·85	29·867
5 0¼	15 9¼	2851·05	19·798	6 2¼	19 5¼	4329·95	30·069
5 0½	15 10	2874·76	19·963	6 2½	19 6	4359·16	30·271
5 0¾	15 10¾	2898·56	20·128	6 2¾	19 6¾	4388·47	30·475
5 1	15 11⅝	2922·47	20·294	6 3	19 7⅝	4417·87	30·679
5 1¼	16 0⅜	2946·47	20·461	6 3¼	19 8⅜	4447·37	30·884
5 1½	16 1¼	2970·57	20·629	6 3½	19 9⅛	4476·97	31·090
5 1¾	16 1⅞	2994·77	20·797	6 3¾	19 9⅞	4506·67	31·296
5 2	16 2¾	3019·07	20·965	6 4	19 10¾	4536·47	31·503
5 2¼	16 3½	3043·47	21·135	6 4¼	19 11½	4566·36	31·710
5 2½	16 4¼	3067·96	21·305	6 4½	20 0¼	4596·35	31·919
5 2¾	16 5⅛	3092·56	21·476	6 4¾	20 1⅛	4626·44	32·114
5 3	16 5⅞	3117·25	21·647	6 5	20 1⅞	4656·63	32·337
5 3¼	16 6¼	3142·04	21·819	6 5¼	20 2⅝	4686·92	32·548
5 3½	16 7½	3166·92	21·992	6 5½	20 3½	4717·39	32·759
5 3¾	16 8¼	3191·91	22·166	6 5¾	20 4¼	4747·79	32·970

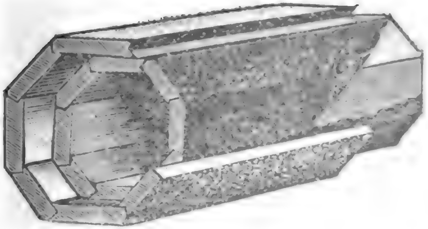
Diameter.	Circumference.	Area.	Side of equal Square.	Diameter.	Circumference.	Area.	Side of equal Square.
feet. in.	feet. in.	square feet.	feet. in.	feet. in.	feet. in.	square feet.	feet in.
6	18 10⅛	28·274	5 3¾	11	34 6⅝	95·033	9 8⅞
1	19 1¼	29·065	5 4⅝	1	34 9¾	96·478	9 9⅞
2	19 4½	29·867	5 5½	2	35 0⅞	97·934	9 10¾
3	19 7⅝	30·679	5 6½	3	35 4⅛	99·402	9 11⅝
4	19 10¾	31·503	5 7¾	4	35 7¼	100·879	10 0½
5	20 1⅞	32·337	5 8¼	5	35 10⅝	102·368	10 1⅜
6	20 5	33·183	5 9⅛	6	36 1½	103·869	10 2¼
7	20 8⅛	34·039	5 10	7	36 4½	105·379	10 3⅛
8	20 11¼	34 906	5 10⅞	8	36 7¾	106·901	10 4
9	21 2⅜	35·784	5 11¾	9	36 10⅞	108·434	10 5
10	21 5½	36·674	6 0⅝	10	37 2¾	109·977	10 5⅞
11	21 8¾	37·573	6 1½	11	37 5¼	111·531	10 6¾
7	21 11⅞	38·484	6 2⅜	12	37 8⅜	113·097	10 7⅝
1	22 3	39·406	6 3⅜	1	37 11½	114·673	10 8½
2	22 6⅛	40·338	6 4¼	2	38 2⅝	116·260	10 9⅜
3	22 9¼	41·282	6 5	3	38 5¾	117·859	10 10¼
4	23 0⅜	42·236	6 6	4	38 8⅞	119·467	10 11⅛
5	23 2⅛	43·202	6 6⅞	5	39 0	121·087	11 0
6	23 6¾	44·178	6 7¾	6	39 3¼	122·718	11 0⅞
7	23 11	45·165	6 8⅝	7	39 6⅜	124·359	11 1⅞
8	24 1⅛	46·163	6 9½	8	39 9½	126·012	11 2⅝
9	24 4⅛	47·173	6 10⅜	9	40 0⅝	127·676	11 3⅝
10	24 7¼	48·192	6 11¼	10	40 3¾	129·350	11 4½
11	24 10⅜	49·223	7 0⅛	11	40 6⅞	131·036	11 5⅜
8	25 1½	50·265	7 0⅛	13	40 10	132·732	11 6¼
1	25 4⅝	51·317	7 1¾	1	41 1⅛	134·439	11 7⅛
2	25 7⅞	52.381	7 2⅞	2	41 4⅜	136·157	11 8⅛
3	25 11	53·456	7 3¾	3	41 7½	137·886	11 8⅞
4	26 2⅛	54·541	7 4⅝	4	41 10⅝	139·626	11 9¾
5	26 5¼	55·637	7 5½	5	42 1⅝	141·377	11 10⅝
6	26 8⅜	56·745	7 6⅜	6	42 4⅞	143·139	11 11⅝
7	26 11½	57·862	7 7¼	7	42 8	144·911	12 0½
8	27 2¾	58·992	7 8⅛	8	42 11⅛	146·694	12 1⅜
9	27 5¾	60·132	7 9⅛	9	43 2¼	148·489	12 2¼
10	27 9	61·282	7 9⅞	10	43 5½	150·294	12 3⅛
11	28 0⅛	62·444	7 10¾	11	43 8⅝	152·110	12 4
9	28 3¼	63.617	7 11⅝	14	43 11¾	153·938	12 4⅞
1	28 6⅜	64·800	8 0½	1	44 2⅞	155·775	12 5⅝
2	28 9½	65·995	8 1½	2	44 6	157·625	12 6½
3	29 0⅝	67·200	8 2⅜	3	44 9⅛	159·485	12 7½
4	29 3¾	68·416	8 3¼	4	45 0¼	161·355	12 8⅜
5	29 7	69·644	8 4⅛	5	45 3½	163·237	12 9⅜
6	29 10⅛	70·882	8 5	6	45 6⅝	165·130	12 10¼
7	30 1¼	72 130	8 5⅞	7	45 9¾	167·033	12 11⅛
8	30 4⅜	73·391	8 6¾	8	46 0⅞	168·947	13 0
9	30 7½	74·662	8 7⅝	9	46 4	170·873	13 1⅛
10	30 11⅝	75·943	8 8½	10	46 7⅛	172·809	13 1¾
11	31 1¾	77·236	8 9½	11	46 11¼	174·756	13 2⅝
10	31 5	78·540	8 10¼	15	47 1½	176·715	13 3½
1	31 8⅛	79·854	8 11¼	1	47 4⅝	178·683	13 4⅜
2	31 11¼	81·179	9 0⅛	2	47 7¾	180·663	13 5¼
3	32 2⅜	82·516	9 1	3	47 10⅞	182·654	13 6⅛
4	32 5½	83·862	9 1⅞	4	48 2½	184·655	13 7⅛
5	32 8⅝	85·221	9 2¾	5	48 5⅛	186·668	13 8
6	32 11¾	86·590	9 3⅝	6	48 8¼	188·692	13 8⅞
7	33 2⅞	87·969	9 4½	7	48 11⅜	190·726	13 9¾
8	33 6⅛	89·360	9 5⅜	8	49 2⅝	192·771	13 10⅝
9	33 9¼	90·762	9 6¼	9	49 5¾	194·828	13 11½
10	34 0⅜	92·174	9 7¼	10	49 8⅞	196·894	14 0⅜
11	34 3½	93·598	9 8⅛	11	50 0	198·973	14 1¼

Diameter.	Circumference.	Area.	Side of Equal Square.	Diameter.	Circumference.	Area.	Side of Equal Square.
feet. in.	feet. in.	sq. ft.	feet. in.	feet. in.	feet. in.	sq. ft.	feet. in.
16	50 3⅛	201·062	14 2⅛	21	65 11⅝	346·361	18 7¼
1	50 6¼	203·161	14 3	1	66 2¾	349·114	18 8¼
2	50 9⅝	205·272	14 3⅞	2	66 5⅞	351·880	18 9⅛
3	51 0½	207·394	14 4⅞	3	66 9	354·657	18 10
4	51 3¾	209·526	14 5¾	4	67 0⅛	357·443	18 10⅞
5	51 6½	211·670	14 6⅝	5	67 3⅜	360·241	18 11¾
6	51 10	213·825	14 7½	6	67 6½	363·051	19 0⅝
7	52 1⅛	215·989	14 8¾	7	67 9⅝	365·869	19 1⅝
8	52 4¼	218·166	14 9¼	8	68 0¾	368·701	19 2½
9	52 7⅜	220·353	14 10⅛	9	68 3⅞	371·543	19 3⅝
10	52 10½	222·551	14 11	10	68 7	374·394	19 4¼
11	53 1⅝	224·760	14 11⅞	11	68 10¼	377·258	19 5⅛
17	53 4⅞	226·980	15 0¾	22	69 1⅜	380·133	19 5⅞
1	53 8	229·210	15 1⅝	1	69 4½	383·017	19 6⅞
2	53 11⅛	231·462	15 2⅝	2	69 7⅜	385·914	19 7¾
3	54 2⅛	233·705	15 3½	3	69 10¾	388·822	19 8⅝
4	54 5⅜	235·968	15 4⅜	4	70 1⅞	391·738	19 9½
5	54 8½	238·243	15 5¼	5	70 5	394·668	19 10⅜
6	54 11⅝	240·528	15 6⅛	6	70 8¼	397·608	19 11⅜
7	55 2⅞	242·824	15 7	7	70 11⅛	400·558	20 0¼
8	55 6	245·131	15 7⅞	8	71 2½	403·520	20 1⅛
9	55 9⅛	247·450	15 8¾	9	71 5⅝	406·493	20 2
10	56 0¼	249·778	15 9⅝	10	71 8¾	409·475	20 2⅞
11	56 3½	252·118	15 10½	11	71 11⅞	412·470	20 3¾
18	56 6½	254·469	15 11⅜	23	72 3	415·476	20 4½
1	56 9⅝	256·830	16 0⅜	1	72 6⅛	418·491	20 5½
2	57 0⅞	259·203	16 1¼	2	72 9⅜	421·519	20 6⅜
3	57 4	261·587	16 2⅛	3	73 0½	424·557	20 7¼
4	57 7⅛	263·980	16 3⅛	4	73 3⅝	427·605	20 8⅛
5	57 10¼	266·386	16 3⅞	5	73 6¾	430·665	20 9⅛
6	58 1⅜	268·803	16 4¾	6	73 9⅞	433·737	20 10
7	58 4½	271·229	16 5⅝	7	74 1	436·817	20 10⅞
8	58 7	273·667	16 6½	8	74 4⅛	439·910	20 11¾
9	58 10	276·117	16 7⅜	9	74 7¼	443·014	21 0⅝
10	59 2	278·576	16 8¼	10	74 10⅝	446·127	21 1½
11	59 5	281·047	16 9¼	11	75 1⅝	449·253	21 2⅜
19	59 8¼	283·529	16 10	24	75 4¾	452·390	21 3¼
1	59 11½	286·021	16 11	1	75 7⅞	455·536	21 4⅛
2	60 2½	288·524	16 11⅞	2	75 11	458·694	21 5
3	60 5⅝	291·039	17 0¾	3	76 2⅛	461·864	21 6
4	60 8¾	293·564	17 1⅝	4	76 5¼	465·042	21 6⅞
5	60 11⅞	296·110	17 2½	5	76 8½	468·234	21 7¾
6	61 3⅛	298·648	17 3⅜	6	76 11⅝	471·436	21 8⅝
7	61 6¼	301·205	17 4¼	7	77 2¾	474·647	21 9½
8	61 9½	303·774	17 5⅛	8	77 5⅞	477·871	21 10⅜
9	62 0½	306·355	17 6	9	77 9	481·106	21 11¼
10	62 3⅝	308·944	17 7	10	78 0⅛	484·350	22 0⅛
11	62 6¾	311·546	17 7⅞	11	78 3¼	487·607	22 1
20	62 9⅞	314·160	17 8⅝	25	78 6⅜	490·875	22 1⅞
1	63 1⅛	316·782	17 9⅝	1	78 9½	494·151	22 2¾
2	63 4¼	319·417	17 10½	2	79 0¼	497·441	22 3¾
3	63 7⅜	322·063	17 11⅜	3	79 3⅞	500·741	22 4⅝
4	63 11½	324·718	18 0¼	4	79 7⅛	504·051	22 5½
5	64 1⅝	327·385	18 1⅛	5	79 11⅛	507·373	22 6⅜
6	64 4¾	330·064	18 2	6	80 1¼	510·706	22 7¼
7	64 7⅞	332·752	18 2⅞	7	80 4⅜	514·048	22 8⅛
8	64 11	335·452	18 3¾	8	80 7⅝	517·403	22 9
9	65 2¼	338·163	18 4¾	9	80 10¾	520·769	22 9⅞
10	65 5⅜	340·884	18 5⅝	10	81 1⅞	524·144	22 10¾
11	65 8¼	343·617	18 6½	11	81 5	527·531	22 11

A. WYCKOFF & SON,

ELMIRA, N. Y.

PATENT STEAM-PIPE CASING



Two staves removed to show lining between inside and outside staves.

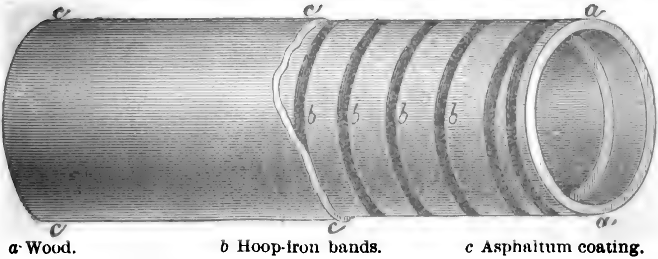
A. WYCKOFF & SON,

ELMIRA, N. Y.,

MANUFACTURERS OF

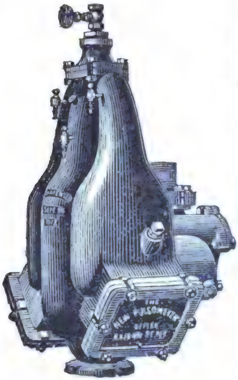
WOOD WATER PIPE,

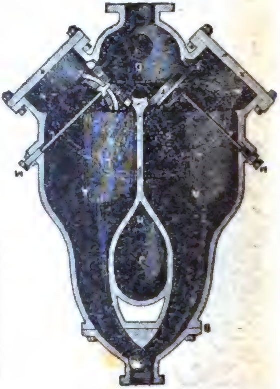
For Coal and Iron Mines, Coke Works, and
General Water Supply.



a Wood. *b* Hoop-iron bands. *c* Asphaltum coating.

Send for Catalogues and Prices.





INDEX.

Absorption—Brass

Tangents—Wire Rope

1
3